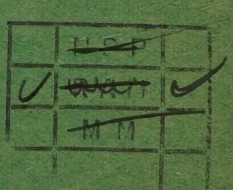
UNIVERSITY COLLEGE OF WALES,
ABERYSTWYTH

WELSH PLANT BREEDING STATION

REPORT
1950 – 1956



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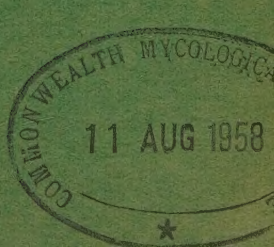

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THE NEW HEADQUARTERS OF THE
WELSH PLANT BREEDING STATION

UNIVERSITY COLLEGE OF WALES,
ABERYSTWYTH

WELSH PLANT BREEDING STATION

REPORT
1950 – 1956

PRICE — — 7/6

2,000/June, 1958

LIST OF STAFF AS AT 31st DECEMBER, 1956

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Assistant Director: Gwilym Evans, M.Sc.

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Martin Borrill, B.Sc., Ph.D. Research Officer
Peter B. Vose, B.Sc., N.D.A. Research Officer
Elfed J. Lewis, B.Sc. Research Officer
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Clover Breeding

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Miss Alice M. Evans, B.Sc. Research Officer
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J. C. Williams, D. R. Evans, Miss J. E. Morgan, Miss M. E. Davies, Miss M. J. Meredith } Assistants (Scientific)

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J. D. Hayes, B.Sc., M.S.(Wisc.). Research Officer
Idris Jones. Assistant Experimental Officer
W. T. H. Peregrine, B.Sc. Assistant Experimental Officer
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Grassland Agronomy

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W. E. J. Milton, M.Sc., N.D.A. Research Officer
D. G. Miles, B.Sc. Research Officer
Ieuan Davies, M.Sc. Research Officer
Arthur Troughton, M.Sc. Research Officer
A. H. Charles, B.Sc. Research Officer
Miss Alison G. Davies, B.A., M.Sc. Research Officer
Miss Sybil W. Edwards, B.Sc. Assistant Experimental Officer

W. B. Evans, J. H. Davies, S. J. Davies, Miss G. Jones, Miss M. M. G. Lewis, Miss B. Davies, Miss J. Davies, Miss M. E. D. Owen, Miss R. M. G. Thomas, Miss M. R. Ballantine } Assistants (Scientific)

Seed Multiplication

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H. M. Roberts, B.Sc. Research Officer
Joseph Lewis, B.Sc. Research Officer
J. L. Stoddart, B.Sc. Research Officer
T. B. Edwards. Assistant Experimental Officer
R. A. D. Pegler, B.Sc. Assistant Experimental Officer
W. J. Evans, J. Yates, Miss M. Howell, Miss D. Lewis } Assistants (Scientific)

Cytology

Keith Jones, B.Sc. Research Officer in charge
Miss Shirley P. Weston, B.Sc. Assistant Experimental Officer
Miss E. E. Davies, Miss F. A. Davies. Assistants (Scientific)

Chemistry

Goronwy ap Griffith, B.Sc., Ph.D. Research Officer in charge
D. Cyril Thomas, B.Sc. Assistant Experimental Officer
Miss H. M. Daniels. Assistant (Scientific)

Assistant to Director for Field Experiments

Llywelyn Phillips, B.Sc.

Assistant to Director for Research in Oats

Ieuan T. Jones, B.Sc. Assistant Experimental Officer

Library: J. R. F. Piette, L.és S. Librarian
Mrs. M. J. Ball. Assistant

ADMINISTRATIVE

Secretary : J. O. Parry-Williams, M.B.E.

Director's Secretary : Miss Irene D. Rees

Chief Clerk : J. D. N. H. Humphreys, A.C.C.S.

Clerical Officers: Haydn Thomas, Miss M. E. Owen, D. Alun Isaac, B. R. H. Rowlands.

Typing Staff: Miss Margaret E. Jones, Miss E. Anne Jones, Miss Eiddwen M. Morris, Miss Sarah E. Jones, Miss M. A. Vaughan Jones, Miss Wendy Leardie.

FARMS

Frongoch

Harry Jones. Manager
Staff 36

Morfa Mawr Seed Multiplication Farm

Glyndwr Phillips, Dip.Agric. Manager
Staff 12

Caretakers, Porters, Part-time Cleaners 7

VISITING RESEARCH WORKERS

Assistant Professor D. P. Bignoli, Argentina, South America. British Council Scholar 1950.

Mr. C. E. Wright, Belfast, Min. Agric. Fish. and Food Post-graduate Scholar 1950–51.

Mr. G. Leme da Roche, Saô Paulo, Brazil. British Council Scholar 1952–53.

Mr. J. D. H. Reusch, Natal, South Africa. 1953–56.

Mr. J. W. Morrow, Belfast, Northern Ireland. Post-graduate Scholarship from Queen's University, Belfast. Intermittent periods during 1953–1954.

Mr. M. M. Habib, Egypt, British Council Scholar 1955–

Mr. A. S. Patel, Anand, Bombay State, India 1955–

Professor Maurice L. Peterson, Univ. of California, U.S.A. Senior Fulbright Scholar 1956–1957.

VISITORS ACCEPTED FOR SHORT PERIODS FOR THE STUDY OF BREEDING AND OTHER EXPERIMENTAL TECHNIQUES

1950	Mr. Magnus Jetne, Norway.
1951	Mr. M. E. Abd el Nabi, Sudan ; Mr. J. Caputa, Switzerland ; Mr. C. Giraldo-Holguin, Colombia, South America ; Mr. Ole Sønderhousen, Denmark ; Mr. A. Vyncke, Belgium ; Mr. D. W. Cowling, Great Britain.
1952	Mr. Robert Best, Netherlands ; Mr. E. D. Bumpus, Southern Rhodesia ; Mr. Huokuna, Finland ; Miss Miller, U.S.A.; Mr. Timothy O'Sullivan, Dublin ; Mr. R. S. Cumming, Mr. A. B. Rains, Mr. Tom Webster, Great Britain.
1953	Mr. Kåre Strande, Norway ;
1954	Mr. A. R. Hart, Cape Province, South Africa ; Mr. Robin Whyle, Cape Province, South Africa ; Mr. Allan Fisher, Natal, South Africa.
1955	Mr. V. Cardoza, Asunción, Paraguay ; Dr. Paul Solberg, Norway ; Mr. W. H. Foster, Great Britain.
1956	Mr. Gabriel Eros, Canada ; Mrs. Jelena D. Pavličič, Yugoslavia ; Mr. Tom Greenaway, Great Britain.

CONTENTS

Preface 8

GRASS BREEDING 11

Initial plant collections and breeding
Potential strains and their purpose
Production of the first generation seed
The search for new plant material
Breeding techniques
The effect of varying the number of parent plants
The diallel cross and the breeding programme
Single plants as a basis of assessment in comparison with drills and plots
The agronomic potentialities of *Lolium perenne* × *L. italicum*
The effect of selection for earlier heading on late-flowering pasture plants of *Lolium perenne*
Variation in nutritional response and requirements in plants of *L. perenne*
Self-fertility in *Phleum*
Genetical studies in *Lolium perenne*
Interspecific and intergeneric crosses
The effect of variation in climatic conditions on date of inflorescence emergence
Effect on heading of differences in micro-climate due to altitude
Date of sowing in relation to the severity of rust infection in timothy
The influence of date of sowing on heading behaviour in timothy
Meteorological conditions in relation to anthesis
Shoot morphology in various *Gramineae*

PLANT GENETICS (GRASSES) 36

Pilot studies on *Lolium*
Transplant studies
Standard greenhouse tests for flowering responses
Genetic control of flowering responses
Genetic structure of populations
Leaf and bud development
Single gene differences in *Lolium*

LEGUME BREEDING 51

Early studies in breeding
Economic breeding
Polyploidy
Potentiality trials
Technique studies

Lucerne agronomy
Genetics and interspecific hybridization
Pathology

CEREAL, BEAN AND *BRASSICAE* BREEDING 66
Aims and results of earlier work
Oats
Winter oats
Spring oats
Breeding for disease resistance
Agronomic investigations
Cytogenetic studies
Induction of mutations in oats through seed irradiation
Study of variation in panicle and culm characters in relation to population density in oats
Barley and wheat breeding
Field beans
Forage kales and rapes

GRASSLAND AGRONOMY 94
Early agronomic investigations
Scheme of strain testing
Preliminary trials
Establishment
Persistency of strains when sown in simple mixtures of one grass with white clover
Persistency of strains when sown in mixtures with companion grasses
Influence of one strain on another of the same species
Winter " burn "
Herbage production studies
Herbage production under grazing management
Herbage production for conservation
The influence of time of application of nitrogenous fertilizers on herbage production
The influence on herbage production of time of cutting in relation to stage of growth
Technique studies on herbage assessment
Animal production trials
Hill land investigations
Improvement of the native hill sward
Improvement of hill land by ploughing, manuring and reseeding
Establishment
(*a*) Soil consolidation
(*b*) Date of utilization of cover crop
Persistency of strains
Production of improved and native swards
Other investigations
Agrotype trial

Studies on the roots and storage organs of herbage plants
Germination and establishment of rush (*Juncus effusus*)
Epidermal characteristics of the leaves and lemmas of some common British grasses.

SEED MULTIPLICATION 129
Strains of grasses and clovers
Foundation or Breeders' Seed
Stock Seed production
Target sowing acreages
Inspection of seed crops of herbage strains for certification
Maximum annual quantities of seed of "S" strains produced
Cereals: Nucleus stocks; Foundation Seed; Seed crop certification
Investigations:
The effect of seed rate and nitrogen on seed crops of leafy grass strains: 1. Wide drills; 2. Broadcast
The effect of a cover crop
Drill width effect on yields
Inter-drill cultivations and seed yields
Fertilizer treatments for seed yield
Inter-harvest grazing and seed yield
Maintenance of life in seeds: 1. Red clover; 2. Ryegrass; 3. Meadow fescue and timothy; 4. Crop and weed seeds

CYTOLOGY 156
The cytology of *Agrostis* spp. and their hybrids
Chromosome interchanges in *Lolium perenne*
Cytological survey of ecotypes of *Dactylis*
Cytology of *Holcus mollis* and *H. lanatus*
Chromosome studies in *Anthoxanthum*

CHEMISTRY 161
Pasture analysis for crude protein determinations
Technique of fibre assessment
Study of chemical and other characters of cereal straw
The ammonium and nitrate status of grassland soils

MORFA MAWR SEED MULTIPLICATION FARM 164
BRIEF DESCRIPTIVE NOTE ON THE NEW WINTER OAT VARIETY POWYS (S.226) 166
BRIEF DESCRIPTIVE NOTE ON S.100 "NOMARK" WHITE CLOVER 167
LIST OF RELEASED STRAINS 167
GENERAL PUBLICATIONS, REPORTS AND REVIEWS 168

PREFACE

The period covered by this Report has been one of development and expansion during which there has been a transfer of the Station's headquarters from the Agricultural Research Buildings, Penglais, to the new centre at Plas Gogerddan.

Conversion of the mansion to provide accommodation for the administrative staff, library, offices and laboratories for Grassland Agronomy, Seed Multiplication, Cytology and Chemistry, was completed in December, 1953, and the transfer of staff proceeded at intervals during the ensuing winter and spring months. Laboratories and greenhouses for Cereal Breeding, Legume Breeding, Grass Breeding and Plant Genetics (Grasses), have been constructed with a central building for soil storage, soil sterilization, potting and other services required by the breeding sections. In 1954 a new building, the Lord Milford Plant Research Laboratories, was erected for the storage of breeding material, sheaves, head-row progenies, single plants and seeds, and to house the threshing and other equipment of the Cereal Breeding and Seed Multiplication Sections. This building also provides additional accommodation for Grassland Agronomy and in the basement provision is made for cold storage rooms for breeders' seed stocks and growth control chambers to facilitate and expedite the crossing and back-crossing of plant material used in the breeding programmes.

The new headquarters and experimental grounds were officially opened by Her Majesty Queen Elizabeth II, accompanied by H.R.H. The Duke of Edinburgh, in August 1955.

On the research side the main developments have been directed towards improving the facilities necessary for the investigation of fundamental problems associated with the furtherance of the breeding programmes.

Additions to the staff of the Cytology Section, established in 1948, enable more attention to be given to problems of inter- and intra-specific hybridization, cytotaxonomy, the occurrence of chromosome races, and to surveys of field populations in a wider range of grass species.

The Chemistry unit, set up in 1953, provides analytical services to breeders and agronomists in respect of nitrogen and fibre determinations, and pursues researches into plant and soil problems independently of, or jointly with, other sections.

The appointment in 1954 of a Plant Geneticist (Grasses) was made for the study of the physiological response of grass species to

variations in temperature and photoperiod, and the genetical study of plant populations. One of the main aims in these studies is to provide basic information on growth phenomena essential to the elucidation of the behaviour of grass strains in leys and their response to different systems of management in the field.

There has been a strengthening of the staff in the Cereal Breeding Section and its sphere of studies has been enlarged to include field beans, kales and rape, the latter as forage crops for autumn and winter keep.

In 1955 arrangements were made with the Council of the National Institute of Agricultural Botany whereby the latter took over, on the Station's behalf, responsibility for the production of Stock Seed of the bred strains of grasses and clovers from Foundation Seed supplied by the Station, its distribution to approved seed growers, and the certification of the crops and seed derived therefrom under the National Scheme for Comprehensive Certification of Herbage Seeds. As a result, the staff of the Seed Multiplication Section is now able to devote more time to research into seed production and seed growing problems and to the propagation and maintenance of clonal material of new and established strains supplied by the plant breeders.

Within the period 1950–1956 the breeding work on several new strains has been completed. Annual supplies of Stock Seed of the new grass strains S.22 Italian ryegrass and S.170 tall fescue, and of the white winter oat Powys (S.226), are being distributed to approved growers for multiplication under crop and seed Certification Schemes; breeders' seed of the new white clover strain S.100 " Nomark " is also being multiplied to provide supplies of approved seed for distribution to seed growers in the near future.

Progress has been made in the development of other strains, some of which are now undergoing trials of field performance; these include a *Phalaris* hybrid derivative which shows a high capacity for maintaining green leafage in February; a tall oat grass strain which remains green into March; a cocksfoot which starts growth very early in spring; a leafy ryegrass with early spring growth coupled with a late-flowering habit; two strains of late-flowering red clover; a higher yielding winter oat of S.147 type, and a number of mildew and eelworm resistant selections of oats for autumn and spring sowing.

Increasing attention in the Grassland Agronomy Section is being given to the evaluation of new and established strains in co-operation with the herbage breeders. This work includes studies of

the effects of time, frequency and intensity of grazing and of cutting techniques on the seasonal development and assessment of herbage production under sward and other cultural conditions. Ecological studies relating to the improvement of native hill pastures by surface treatments are being pursued as well as detailed studies of root systems and stem bases as storage organs in relation to growth and recovery after defoliation and the effects of roots of different species on soil structure and soil fertility.

Library facilities and publications

The Station library comprises a wide range of scientific journals relating to plant research which are being supplemented from year to year. More recent accessions include a number of reference books, periodicals and pamphlets on biological subjects.

This Report, which deals with the main experiments in progress during the years 1950-1956, is presented in eight sections and concludes with a brief account of the organization and function of the Morfa Mawr Seed Multiplication Farm.

A list of scientific papers published during this period is given at the end of each section of the Report ; other papers are cited in the list of general publications, reports and reviews ; references to earlier publications may be found in the " Bibliography of Articles, Reports and Scientific Papers by Members of Staff 1919–1955."

Acknowledgement

It is a pleasure to express my gratitude and thanks to Mr. Gwilym Evans, Dr. D. J. Griffiths, Dr. J. P. Cooper, and Miss Irene D. Rees, who have undertaken the task of collating and editing this Report in preparation for the press.

E. T. JONES,
Director.

Welsh Plant Breeding Station,
Plas Gogerddan,
Nr. Aberystwyth.
31*st December*, 1957.

GRASS BREEDING

By A. R. Beddows

When the Station was established one of the first steps taken to initiate the grass breeding programme was to assemble as comprehensive a collection of plants as possible of those species generally employed in laying down land to grass. Seeds were therefore obtained from Europe and from many countries overseas, while from the United Kingdom inflorescences and plants were widely collected.

Initial plant collections and breeding

Stapledon started collecting cocksfoot in 1918 and within a few years 11,328 individual plants from 458 collections had been planted out.[1]

Comparable collections of many species were simultaneously made by Dr. T. J. Jenkin from the fattening pastures of the Midlands, from Kent, Somerset, Wales and Ireland; William Davies also collected from Lincolnshire and Buckinghamshire, and later brought home extensive collections from New Zealand, Australia and the Falkland Islands.

When plants of indigenous material from these early collections were grown singly in the nursery they showed from their growth form that plant type was governed to a very considerable extent by the management of the different habitats. In other words, the effect of the biotic factor exerted a strong selective influence so that the surviving forms were different from those obtained from the seeds then available in commerce.

Breeders made selections from the wide range of variation found in the plants, one result of which was the marketing of three strains of perennial ryegrass, each of which served to extend the agricultural usefulness of this species: namely S.24, an early flowering, early leafing strain for spring grazing and hay or for continuous grazing; S.101 a fairly late-flowering pasture/hay, dual-purpose strain, and S.23 a late flowering very persistent grazing strain. Comparable strain types were also developed for cocksfoot, timothy and meadow fescue.

Except for those concerned with the earlier phases of the Station's work, it is, as T. J. Jenkin has said, "difficult to realise how little was known in 1919 concerning even the most common grass species."[2]

[1] Stapledon, R. G. 1928. *J. Ecol.* 16. 71–104.
[2] Jenkin, T. J. 1946. *Farming* 1. 141–148.

Our knowledge of what is now called the breeding systems of plants, i.e., their flowering habits, self- and cross-fertility, had to be learned from observation and experiment. One problem which soon faced the breeder was how he could intercross selected plants and be certain that the progeny obtained was due to the hybridization of only the two parent plants. T. J. Jenkin provided a technique which enabled this to be achieved, and in so doing laid the foundation of his classical studies into interspecific and intergeneric hybridization, especially in *Lolium* and *Festuca*. His technique of emasculating the hermaphrodite florets in the grasses was of outstanding value to grass breeding and genetical work.

It now became possible to progeny-test different pairs of plants, indeed to test each of any number of selected plants, to certain standards of vegetative growth, date of flowering etc. These could be crossed under controlled conditions with every other plant in the group to give information through their offspring of the crossing qualities and breeding characteristics of each plant. This enabled the best parents to be discovered and brought together to form the basis of our strains.

During the six-year period under review, two further grass strains were put on the market: S.22 Italian ryegrass, bred for grazing and hay, released in 1951, and S.170 tall fescue, a strain for very early grazing and conservation, in 1955, which brings the total number of S grass strains released to fourteen.

The developments in the study of the grasses outlined in this Report stem directly from, and are a continuation of, the earlier work.

The year 1955 was memorable in respect of T. J. Jenkin's work on wide crosses because it saw the completion of the catalogue of his large herbarium in which about 900 different plants are represented by some 11,000 sheets. In addition to the material available for consultation at the Welsh Plant Breeding Station sets of herbarium sheets have been presented to the National Museum of Wales, Cardiff; The Herbarium, Royal Botanic Gardens, Kew; Natural History Museum, South Kensington, London; Department of Botany, Durham; the Smithsonian Institute, Washington D.C., U.S.A., and The Commonwealth Scientific and Industrial Research Organisation, Canberra, Australia.

Potential strains and their purpose

New collections of seeds and living material have been made of our common cultivated species in order to uncover types different from those found in the available strains. In a similar way we have

extended our search to species not now normally employed in agricultural practice in the United Kingdom.

During recent years breeding work has been intensified, and seed of several potential strains is now being used in agronomic trials ; until their agronomic assessment has been completed they are only of potential worth. The primary purpose of most will be to provide keep during the difficult periods of the farmer's year, and to provide herbage at other times.

Two new strains of perennial ryegrass have been produced, the first, a late-flowering type, intended for late autumn/early winter grazing, and the second, flowering in mid-season, is a green foggage type primarily for grazing in late winter or very early spring (February–April).

A hay type of timothy is being developed which is taller, more erect, darker green and earlier heading than S.51.

In cocksfoot also we have a strain the plants of which are early-heading and are expected to give fresh-growing herbage earlier in the spring than American or Danish ; the plants are erect, and have good aftermath growth. It is also expected that animals may be able to keep this early cocksfoot well grazed and so largely prevent the development of panicles.

A form of tall oat grass (*Arrhenatherum elatius*) has been selected which will still be in the leafy stage when plants of the normal hay type have developed inflorescences.

Meadow foxtail has long been under investigation at the Station, but during recent years work on it has been revived. The best material from a strain developed by Sir George Stapledon, and plants from new sources, are being used in its breeding. Its most important use may be the provision of herbage during the midsummer gap rather than the production of early spring keep which is generally regarded as the chief merit of this species. Another potential strain, which has also been maintained for several years, is that derived from hybrids between *Phalaris arundinacea* and *P. tuberosa* produced by T. J. Jenkin. A large population of single plants of this hybrid-derivative canary grass has been grown and new selections made from among them to establish the strain.

We have in addition two new strains, one of bent grass (*Agrostis tenuis*) and the other of sweet vernal grass (*Anthoxanthum odoratum*), both of which may be more useful in the less fertile marginal areas.

More recently Martin Borrill has studied diploid and tetraploid *Dactylis* populations, obtained from Mediterranean and Portuguese habitats, amongst which he has found plants with useful agronomi

characteristics. Crosses have been made within these groups, and also between them and plants of North-European origin.

In addition to the development of new strains, work with existing strains has continued. In particular the original three cocksfoot strains have had their distinctive growth form re-established and have now been separated in respect of the date of panicle emergence. This has entailed introducing into each of the strains material not previously present in them.

Production of the first generation seed

During the period under review there has been a change in the Station's policy regarding the production of first-generation seed of the grass strains. This was formerly the responsibility of the breeder who decided on the size of the seed island, and the number of clonal units of each parent plant to be included; seed harvested from the island was handed over to the Seed Multiplication Officer who assumed responsibility for subsequent increase. Under the new system, the production of Foundation Seed of marketed strains is entirely the concern of the Seed Multiplication Section, to which the breeder supplies the parental plants.

A living plant "Museum" of parental material of all strains, whether on the market or still under investigation, has been established.

The search for new plant material

Reference has already been made to the great variation which is to be found within the different species, and of its value as breeding material. We are convinced of the unexhausted potential of this natural variation, and have therefore again embarked on a programme of extensive plant collection. Seed-bearing inflorescences in great number have been gathered from the South-West of England, and Western France, and plants have been again taken from the fattening pastures of Leicestershire, from Buckinghamshire, Kent and the North of England. In this work we have been greatly helped by the grassland officers of the National Agricultural Advisory Service.

Special mention must be made of the material provided by Mr. A. F. Money-Kyrle, who collected inflorescences in Finmark within the Arctic Circle, when as a member of the Cambridge Expedition he visited the area in 1950. He also subsequently sent us samples collected when he accompanied the "Men of the Trees" Expedition in 1953 through North Africa.

We are grateful to Dr. R. O. Whyte, Agronomist, and Mr. Ch. O. Rossetti, Seed Multiplication Officer, Plant Production Branch, Agriculture Division, F.A.O., Rome, for their assistance in 1956 in providing plants grown near Rome from seed collected in countries bordering the Mediterranean and also for original and once-grown seed. The material represented several genera and species, but the greater proportion was of *Dactylis*, and these plants have already proved of considerable interest in our genecological studies. From these introductions we hope to select plants which may form the basis of new strains differing in some special feature from those already in use. These collections also provide material for *ad hoc* scientific investigation. Any plants selected for further study are transferred to a special nursery block and later broken down into clonal units, the best of these being subsequently used as parents in hybridization programmes.

Breeding techniques

The next step is the testing of the genetic potentialities of the prospective parents by selfing and intercrossing within their own groups. The method of intercrossing giving the greatest control and most information, is that of hand-pollination after emasculation in a series of diallel crosses. This method is practical only in plants whose florets are sufficiently large to permit of a relatively easy extraction of the anthers.

An alternative procedure is the isolation of the selected plants, either in a greenhouse or out of doors, the latter method permits the testing of larger numbers of potential mother plants, which can be clonally randomized within the isolation area. In this way differential pollination is reduced and more seed is obtained. This technique, now referred to as the Polycross Method, has long been used at the Station, but rather as a means of producing breeder's seed than for the testing of possible parents.

In the following year progenies from intercrossed and selfed plants are grown and particular attention is paid to the occurrence of deleterious recessive types, while the outcrossed progenies are examined for vigour and trueness to type. One, or perhaps several, further series of progeny tests may be carried out in this way before a decision is reached as to the merits of a plant. The final operation will be the isolation for interpollination of these élite plants, and the production of sufficient seed for agronomic tests.

Several aspects of breeding techniques are being investigated. One such is concerned with the number of mother plants which

can be used to provide an adequate basis for a vigorous and stable strain.

The effect of varying the number of parent plants

In a normally outbreeding species, a strain based on one plant or on a very small number of plants is liable to show a decline in vigour in successive generations as a result of inbreeding. Strains based on many plants while not exhibiting inbreeding depression might become more variable and show a " shift " in certain characters, e.g. date of head emergence resulting from harvesting on the early side over several generations of seed multiplication. On the other hand strains based on a very large number of individuals involve more time and labour in the maintenance of the basic plants. We are therefore investigating in *Lolium perenne* the effects of using different numbers of parent plants on the vigour and variability of successive generations.

As a first step, seven plants of perennial ryegrass selected for their earliness of heading were diallel crossed, the progenies were planted out and data on heading and green weights collected. The mean dates of heading ranged from 13 April to 28 April, 1953, and the mean yield per plant in the progenies from 18 oz. to 36 oz.

The parent plants for the experimental strains were chosen according to their combining abilities, as judged by the yield of their progenies. Strains were then built up from combinations of two, three, etc., plants until in one group all seven parents were used. The resulting strains have now reached the third generation of multiplication, and one further increase will be made. The seed of each generation is stored in a refrigerator to maintain viability ; in this way we shall be able to test the different generations of the various strains by growing them simultaneously under uniform conditions. Any changes which may have taken place in the character of the strains can be compared and related to the parents used to produce the first generation in each case.

The diallel cross and the breeding programme

The F_1 plants from the diallel crosses referred to in the previous section were planted out in the field with the I_1 progenies and clones of the original parents. The layout was in accordance with that advised by Dr. J. L. Jinks, of the A.R.C. Biometric Research Unit, University of Birmingham. During the growing season of 1956 data were collected on the dates of head emergence, green weights at the flowering stage and in the aftermath, and the number of in-

florescences present in each cut. These data will be examined in 1957 to see whether F_1 and I_1 data can be utilized to speed up the sorting out of the best plants for use as parents in a breeding programme. The above problems are being investigated by a team consisting of Dr. Betty Cocks (now of Botany Dept., Univ. Coll. London), A. R. Beddows, P. B. Vose and Elfed J. Lewis.

Single plants as a basis of assessment in comparison with drills and plots

The evaluation of parent plants by means of the progeny test, is based on individual spaced plants. A comparison between this method of assessment and that of sown drills and broadcast plots in the evaluation of families and strains was made by A. Lazenby (now of School of Agriculture, Cambridge). In this investigation four strains of perennial ryegrass, Devon Eaver, Irish, New Zealand and S.24 were used, as well as New Zealand Short Rotation ryegrass, H1.

Two forms of management were employed : hay/aftermath, and cutting four times. Each section was laid out in a 5 x 5 Latin Square, with each plot split into three random sub-plots, (i) single plants, (ii) sown drills, (iii) broadcast.

In addition to yield data, information was also collected on the emergence of inflorescences, variation in the number of heads and the proportion of stem to leaf at hay time, inflorescence production in the aftermath, winter survival and the incidence of disease.

The relative total green weight yields for both 1952 and 1953 are shown below with those for H1 given as 100. The figures in brackets show the ranking in each case.

Hay and Aftermath

Strain	*Single plants*		*Sown drills*		*Broadcast plots*	
	1952	1953	1952	1953	1952	1953
H1	100(1)	100(2)	100(1)	100(3)	100(1)	100(3)
S.24	72(2)	110(1)	89(2)	104(1)	85(3)	101(2)
New Zealand	68(3)	95(3)	88(3)	102(2)	87(2)	104(1)
Irish	53(4)	73(5)	78(4)	91(5)	79(4)	95(4)
Devon Eaver	50(5)	78(4)	75(5)	92(4)	77(5)	93(5)

	Cut Four Times					
H1	100(1)	100(2)	100(1)	100(2)	100(1)	100(1)
S.24	61(3)	114(1)	76(3)	110(1)	68(4)	99(2)
New Zealand	63(2)	88(3)	81(2)	97(3)	79(2)	100(1)
Irish	50(5)	76(5)	62(5)	82(5)	70(3)	93(3)
Devon Eaver	52(4)	78(4)	71(4)	83(4)	66(5)	89(4)

The data indicate that the five strains fall into three categories : (i) H1 ; (ii) S.24 and New Zealand ; (iii) Irish and Devon Eaver. It is a matter of satisfaction to the breeder to find that the grouping of the strains on the basis of drills or plots tends to be similar to that from single plants.

The data appear to justify the use of single plants as a preliminary method of assessing strain and population differences, and this system has the additional advantage of throwing into relief individual variation within populations.

The agronomic potentialities of *Lolium perenne* × *L. italicum*

These two species, which differ in their agronomic characters, present no difficulties in hybridization since they are fully inter-fertile. Italian ryegrass produces early and bulky spring growth but usually behaves as a biennial, in contrast to the more persistent nature of *L. perenne*. The potentialities of hybrids between the two species were under investigation initially by Dr. Betty Cocks, and continued by P. B. Vose.

Intercrosses have been made between plants of S.22 Italian ryegrass and those from the early- and late-flowering pasture-hay strains of perennial ryegrass, S.24 and S.101. Of the 154 families planted in the field, 81 were F_1, the remainder intra-strain progenies and inbred families. These were scored for various characters and preliminary analysis of the data indicates reciprocal differences in percentage germination, seedling leaf length and size of plants. The extent of these differences is indicated as follows :

Cross	Seed Viability	Length of seedling leaves		Height of one-year old plants on	
		First	Second	5.4.55	23.4.55
L. italicum × *L. perenne* (early type)	100	100	100	100	100
Reciprocal	77.1	91.5	95.3	85.4	84.4
L. italicum × *L. perenne* (late type)	100	100	100	100	100
Reciprocal	67.6	91.1	90.5	83.7	76.4

Germination differences have been confirmed in seed from a subsequent series of crosses, but the length of first and second leaves was not measured in the seedlings.

THE EFFECT OF SELECTION FOR EARLIER HEADING ON LATE-FLOWERING PASTURE PLANTS OF *Lolium perenne*

Experience with the certification of field stands of S.23 perennial ryegrass in the first years of the inspection of the " S " strains revealed that some stands contained plants which were rather earlier heading than was normally found in this strain. Some of these aberrant types were obviously " volunteers ", in other cases, however, the explanation for their appearance was not clear. An investigation was therefore initiated to find out to what extent there might be any hidden variation for date of inflorescence emergence in late-flowering plants of *Lolium perenne.*

In the late summer of 1940 seed was available of six families from intercrosses between five basic plants. These six progenies were used to test the effect of selection pressure for earlier heading. The earliest plants to emerge in each family in 1941 were crossed and the seed obtained sown. The earliest emerging plants from these families were crossed in the following year and the process repeated in each of seven succeeding generations.

When the eight generations were grown alongside in the same season under uniform conditions, it was found that selection had produced families some of which were nearly three weeks earlier in mean date of ear emergence than those of the first generation. The effect of earlier heading on growth form was, however, relatively slight. Although the plants were rather laxer and had slightly

taller inflorescences the total number of inflorescences and the green weight showed no consistent change. This result is of considerable agronomic importance as it means that although in practice a " shift " in date of inflorescence production can occur after several generations of seed multiplication, the important agronomic characteristic of high tillering, i.e. persistency, was not seriously changed.

One consequence of this work and of experience gained in the field has been the reduction in the number of seed generations taken, a practice which has greatly diminished the risk both of changes following from unconscious selection by early harvesting, and of contamination.

Variation in nutritional response and requirements in plants of *L. perenne*

A great deal of work has been carried out on individual factors affecting crop yield, but little is recorded of investigations into the basic causes of the varying performance of plants or strains of similar climatic and edaphic adaptation under identical conditions of soil, nutrition and climate. A knowledge of the fundamental causes of strain variation in productivity would be useful to the breeder.

A start has therefore been made by P. B. Vose to evaluate the possible contribution of nutritional factors to strain variation and productivity in the case of perennial ryegrass.

The first experiment concerned three strains selected on the basis of a progeny test : one high yielding, one poor yielding, and a third selected as being intermediate. The three strains were grown in water culture at two levels of nutrition and the plants subsequently analysed. The actual rate of uptake of N, P and K was measured on two occasions during the experiment. A first analysis of the results indicated that there was no measurable difference between strains in the rate of salt uptake, nor was there a significant difference in the utilization of nutrients as measured by analysis of the plants. There was, however, a significant difference between the shoot/root ratios of the high- and low-yielding strains when grown on the high nutritive plane. There was also a significant, but not great, difference between the dry weights of high- and low-yielding strains when grown on the high plane, but not on the low plane. This suggests that response to high fertility is best in the high-yielding strain.

Apart from subsidiary effects, the main conclusion to be drawn from this experiment is that the superiority in the field of the high-

yielding strain over the low-yielding is primarily due to enhanced root growth and a smaller shoot/root ratio. In water culture, nutrients are readily available so that plants with poor root development are at no great disadvantage. Plants with the capacity for extensive root growth will therefore show to advantage if they are given ample room for development, as under spaced plant conditions in the field.

SELF-FERTILITY IN *Phleum*

The work of testing the self-compatibility of plants from various populations was continued. The data available are summarized below :—

	No. of plants tested	*Number of plants with*						*No. of selfing units involved*
		Nil seed in any unit (sterile)		*Seed in some units*		*Seed in every unit*		
			%		%		%	
Hexaploid ($2n = 42$)	141	31	21.9	53	37.6	57	40.4	559
I_1	83	39	46.9	29	34.9	15	18.1	312
I_2	35	25	71.4	3	8.6	7	20.0	62
Diploid ($2n = 14$)	54	40	74.1	14	25.9	0	0.0	244

The results of the germination of the 1955 seedlings show that of the hexaploids tested, 25 proved self-compatible, but of these only 11 gave non-normal as well as normal green seedlings ; 4 gave albinos, 3 gave pale-greens, and 4 gave both albinos and pale-greens.

One plant gave pale-green seedlings whose colour reacted to temperature. Pale-green and normal-green seedlings were transplanted during January into boxes of soil in the greenhouse. Later, the pale greens could only be distinguished from their position in the box. It is thought that the greater photoperiod from the lengthening days coupled with increasing temperatures in the greenhouse due to more sunshine as well as the artificial heat caused the intensification in colour.

A comparable character which is only noticeable during the winter has been found in adult plants in *Phleum nodosum*.

It will not be possible to obtain data for germination and seedling types of the 1956 tests in time for inclusion in this report.

Genetical studies in *Lolium perenne*

In the initial selection of plants in a strain-building programme the most vigorous of the required type is usually chosen for further study. Such plants are almost invariably found to be heterozygous for non-normal seedling types when selfed. In *Lolium perenne*, T. J. Jenkin studied the following characters: albino, yellow-tipped albino, pale green, yellow, lethal green, dwarf green and absence of anthocyanin. He found there was close linkage between the genes for dwarfism (*d*), yellow-tipped albino (*y*), and one of the complementary factors controlling anthocyanin pigmentation (*r*).

A survey of samples of *Lolium perenne* grown from seed of different geographic origin has been carried out by means of selfing and by crossing with tester-plants, each heterozygous for *d*, *y*, and *r*. Every population has been found to be carrying a range of recessive mutant types in the heterozygous state. Although the data are rather restricted, there is a strong suggestion that some of the mutant types occur in all populations.

Of the 468 plants investigated by selfing, 49 produced no seed and could be tentatively regarded as self-sterile, 38 gave too few seeds to provide an adequate test and 268 gave only normal green progenies. The remaining 113 plants gave recessive types in the following proportions :—

		per cent.
Pure albinos Yellow-tipped albinos Green-tipped albinos	56	40.8
Surviving pale and yellow-greens	28	20.4
Lethal greens Lethal pale and yellow-greens	22	16.0
Variegated	7	5.1
Nil anthocyanin (non-reds *c* and *r*)	17	12.4
Indefinite	7	5.1
	137	99.8

The difference between 113 and 137 is accounted for by the fact that some plants were heterozygous for two, and others for three, mutants.

The base colour mutants have proved useful as genetic markers and Griffiths (now in charge of Cereal, Bean and *Brassicae* Breeding) used non-red plants (*ccRR*) to determine the effects of isolation distance on the degree of pollen contamination (Griffiths, 1950). Any outcrossing would be revealed by the presence of red-base plants in the progeny.

INTERSPECIFIC AND INTERGENERIC CROSSES

The object of these studies is to assess the genetic relationship between species of the same and different genera, and to examine the population structure of individual species. One of the classic investigations in this field was made by T. J. Jenkin on the interspecific and intergeneric hybrids in *Lolium* and *Festuca*. Such studies have now been extended to include the genera *Agrostis* (bent), *Dactylis* (cocksfoot), *Holcus* (fog), *Anthoxanthum* (sweet vernal), and *Alopecurus* (foxtail).

Lolium and *Festuca*. Recent work on *Lolium* and *Festuca* has been concerned with the relationships between *Lolium italicum* (Italian ryegrass) and *Festuca arundinacea* (tall fescue). Hybrids between these species were found to occur amongst the progeny from inflorescences of *L. italicum* collected in France by A. R. Beddows. These plants were characterised by branched panicles, and the presence of asperities on the auricle edges ; all were male-sterile. Such hybrids have since been produced by crossing the two species under controlled conditions. Five direct crosses gave viable seed, but only three of the reciprocal crosses (with *L. italicum* as pollen parent) gave viable seed in the germination tests. Backcrosses to the natural hybrids, using pollen from unrelated plants of *L. italicum* and *F.arundinacea* were not successful. These results provide further evidence to support the view that the genera *Lolium* and *Festuca* are related.

Agrostis. The genus *Agrostis*, according to Philipson,[1] contains six species of which the following were studied by W. Ellis Davies (Davies, 1953), now in charge of Legume Breeding.

Agrostis canina var. *fascicularis*	($2n = 14$)
,, ,, ,, *arida*	($2n = 28$)
,, *tenuis*	($2n = 28$)
,, *stolonifera*	($2n = 28$)
,, *gigantea*	($2n = 42$)

[1] Philipson, W. R. 1937. *J. Linn. Soc. Bot.* 51. 73–151.

Cytological studies were carried out by Keith Jones. Fertile or partially fertile interspecific hybrids were obtained in controlled reciprocal crosses between the species as follows :

Cross	*Fertility of F_1 hybrids*
Agrostis canina var. *fasciculatis* × *A. canina* var. *arida*	Nil
A. tenuis × *A. canina* var. *arida*	Moderate
A. tenuis × *A. stolonifera*	Low
A. tenuis × *A. gigantea*	Good
A. stolonifera × *A. gigantea*	Good

Some of the difficulty in identifying *Agrostis* spp. is due probably to the occurrence in nature of interspecific hybrids. From the results of the controlled crosses it can tentatively be concluded that *A. tenuis* is more closely related genetically to *A. canina* var. *arida* than to *A. stolonifera,* and that both *A. tenuis* and *A. stolonifera* are genetically related to *A. gigantea.* The cytological results agree with this view. A further point of interest lies in the fact that the *Agrostis canina* complex appears to contain two species, one diploid, the other tetraploid. According to Hubbard[1] *Agrostis canina* var. *fasicularis* is now *A. canina* subsp. *canina* while *A. canina* var. *arida* should be known as *A. canina* subsp. *montana.*

Dactylis. The genus *Dactylis* contains the valuable tetraploid forage grass *D.glomerata* ($2n = 28$), but aneuploid forms $2n = 26$ to 30 are not uncommon. Two diploid species ($2n = 14$) *D. aschersoniana* from Europe and *D. voronovii* from South-east Europe and Asia are being investigated. One of these, *D. aschersoniana* (*D. polygama* Horvats.), has been found in Buckinghamshire by C. E. Hubbard of Kew. The study of these has been taken over from A. R. Beddows by Martin Borrill.

The variation of morphological type in *D. glomerata* is very great, ranging from the small, stiff, glaucous, short-leaved plants with compact ovate heads (= var. *hispanica* or var. *collina*) found in the Mediterranean region, to the large plants usually found in Britain. Control crosses have been made between tetraploid plants of different morphological types and all were fully inter-fertile.

Interspecific hybrids have been obtained under controlled conditions between the following species :

[1] Hubbard, C. E. 1954. Pelican Book A.295. pp. 428.

D. glomerata ($2n = 28$) × *D. aschersoniana* ($2n = 14$)
D. glomerata × *D. voronovii* ($2n = 14$)
D. aschersoniana × *D. voronovii* and reciprocal

The diploids were inter-fertile, and when crossed with tetraploids gave triploid F_1 hybrids which were vigorous and morphologically intermediate between the parents.

It appears that the genetic differentiation underlying the variation in morphological type has not led to limitation of the capacity for gene exchange either at the diploid or at the tetraploid level.

The number of F_1 plants obtained from crosses between diploids and tetraploids varied greatly, but sufficient triploids ($2n = 21$) were produced to enable Keith Jones to make a comparison of pairing affinities at meiosis of diploid genomes with the single tetraploid genotype used as tester.

These triploids are being tested in a series of crosses to see if it is possible to use them as a means of gene exchange between tetraploid and diploid *Dactylis*. The triploids have proved to be partially female-fertile although male-sterile.

Holcus. The genus *Holcus* is being studied by A. R. Beddows who has made controlled crosses between *H. lanatus* (Yorkshire fog) and *H. mollis* (creeping soft-grass). The F_1 plants were male-sterile with non-dehiscent anthers, and attempts to backcross these hybrids proved unsuccessful. On the basis of the information available when the crosses were made, both species were regarded as diploid ($2n = 14$) and the fact that the F_1 hybrids were male-sterile was not regarded as unusual in view of Jenkin's work with the diploid *Lolium* species. In 1953, when F_1 plants were analysed cytologically by Keith Jones, they were found to be aneuploids ranging in number from $2n = 21$ to $2n = 42$. In view of this the parents were examined confirming that *H. lanatus* is diploid with $2n=14$, but that *H. mollis* from various localities consisted of a polyploid series having $2n = 28$ 35, 42 and 49. All these plants were morphologically rather similar.

Aneuploids had not been found amongst plants collected in the field, but a few were obtained in caryopses from open-pollinated panicles of *H. mollis* harvested from wild plants, and also in seed obtained from botanic gardens when germinated in the laboratory. Such seedlings are very weak, which probably explains their rarity in nature.

There is some evidence to suggest that the self-fertility of *H. mollis* improves with increasing chromosome number; this is illustrated by the following data:

Chromosome No.	Number of plants Tested	Giving seedlings	Percentage of plants giving seedlings
28	30	1	3
35	27	6	22
42	10	5	50
49	5	5	100

The female-fertility of all the races was found to be very similar when the plants were allowed to interpollinate, but much lower than in *H. lanatus* as is shown by the following data :

Species	Chromosome No.	No. of seedlings per plant (Range) (Mean of two panicles)	Mean
H. mollis	28	1 – 44	15
,,	35	2 – 27	23
,,	42	1 – 66	18
H. lanatus	14	22 – 429	185

A fairly extensive crossing programme was also carried through to test the compatibility of the different *H. mollis* races with each other and with *H. lanatus* ; a summary of the crosses which have been tried is shown below :

Female parents	Pollen parents 2n = 14	28	35	42	49	No. of crosses.
H. lanatus 2n = 14	10	12	–	3	4	29
H. mollis 2n = 28	11	7	–	7	1	26
,, 2n = 35	2	2	7	1	–	12
,, 2n = 42	5	1	–	4	–	10
,, 2n = 49	–	–	–	–	1	1
Triploid 2n = 21	16	11	3	3	–	33
						Total 111

The attempts made to intercross tall oat grass (*Arrhenatherum elatius*) 2n = 28 with *Holcus lanatus* (2n = 14) and *H. mollis* 2n = 28 and 42 proved unsuccessful.

Anthoxanthum. The genus *Anthoxanthum* contains three species: *A. odoratum* ($2n = 20$) a perennial widely distributed in temperate regions, is cytologically an autotetraploid and all plants examined by Keith Jones are heterozygous for chromosome interchanges. *A. alpinum* ($2n = 10$) is a perennial occurring in the alpine habitats of Norway, Sweden and Switzerland, and *A. puelii* ($2n = 10$) a Mediterranean annual. New methods of bagging have had to be developed by Martin Borrill for handling these species as the normal bagging technique could not be employed. Successful crosses have been made between the annual diploid *A. puelii* and the perennial tetraploid *A. odoratum.* A cytological examination of the seedling plants made by Keith Jones has shown that all progenies contained a high percentage of triploids.

Crossing was more successful when the tetraploid was used as the female, giving a seed-set of 45% in 15 crosses compared with 20% in 7 crosses with the diploid as female. Plants grouped for intercrossing and isolated by distance gave a higher seed set (54%) than hand-pollinated units (34%).

Only a few crosses were made between the perennial diploid and *A. odoratum,* or between the two diploid species. The results obtained suggest that these crosses are less compatible than the cross between *A. puelii* and *A. odoratum.*

Although *A. alpinum* is morphologically very similar to *A. odoratum* it is less closely related to it than is the phenotypically distinct *A. puelii.*

Alopecurus. The genus *Alopecurus,* which is being studied by Elfed J. Lewis, is comparatively rich in species, showing a wide range in chromosome number from $2n = 14$ to 112. A start has been made to build up a collection of the 6 species native to the British Isles, namely,

A. myosuroides (*A. agrestis*)	$2n = 14$
A. pratensis	" 28
A. geniculatus	" 28
A. aequalis (*A. fulvus*)	" 14
A. bulbosus	" 14
A. alpinus	about 112

THE EFFECT OF VARIATION IN CLIMATIC CONDITIONS ON DATE OF INFLORESCENCE EMERGENCE

Plants have long been known to react to changes in their environment, and especially to weather conditions in the spring. In the course of our work we have observed these responses in the grasses. About 1925 T. J. Jenkin began to record the dates at which

inflorescence emergence commenced in the grasses, this stage being easier to observe than commencement of anthesis. The method adopted by T. J. Jenkin for this was to record the date on which the third inflorescence in a plant came into view through the sheath.

The recording of emergence in this way has continued up to the present day. We now have data available for a period of 30 years for Irish perennial ryegrass and less complete records for other species and strains. The mean date of emergence for Irish ryegrass based on data for the 30 years is 8 May. In a year for which the date approximates to this mean we may perhaps claim to have experienced a normal spring. It was only in 1935 that the mean emergence fell on this date. There is a difference of 22 days in mean date between the most forward spring and the most backward. The sequence in which the emergence dates occur for the various strains is approximately the same in all years. Mean emergence dates at Gogerddan for 1954 are given in the following table for marketed and potential grass strains.

Information on mean date of emergence is of practical significance since it indicates the time and sequence in which each strain is likely to give the best protein : bulk ratio, in other words the time for each strain when silage making or conservation by drying should be in progress. It is important when sowing mixtures for either of these purposes to employ in each mixture only strains with the same date range for inflorescence development.

Investigating the relationships of changes in emergence date with climatic variations it became apparent that there was a fairly obvious inverse correlation between the mean date of emergence and the accumulated temperature for the two or three months preceding the appearance of inflorescences. J. P. Cooper, who has done considerable work on the effects of photoperiod and temperature, confirmed this relationship.

Effect on heading of differences in micro-climate due to altitude

In view of the above relationship we were glad to co-operate with the Department of Geography, University College of Wales, in growing clones at each of the 9 meteorological stations which they have set up for the study of local variations in climatic conditions. The stations lie on a transect running N.E. from an elevation of about 15 ft. at Aberystwyth to 950 ft. on the hills and vary in aspect and exposure. At each site, plants of *Lolium perenne*,

Table of mean dates for inflorescence emergence in 1954, a rather late season, showing the maturity trends of various grass strains grown as single plants at the Welsh Plant Breeding Station, Gogerddan, 1953–54

	May															June															July		
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	31	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	2	4	6
Perennial ryegrass																																		
7 Devon Eaver																																		
12 S.24																																		
14 Irish																																		
16 New Zealand																																		
24 Potential *S* Strain (late winter fodder)																																		
28 Kent Indigenous																																		
3 S.101																																		
7 S.23																																		
10 Potential *S* strain (early winter fodder)																																		
Italian ryegrass																																		
26 H1 N.Z. Short Rotation ryegrass																																		
26 Irish																																		
26 New Zealand																																		
31 S.22																																		
Cocksfoot																																		
2 Potential *S* strain (early fodder)																																		
8 American																																		
15 Danish																																		
18 S.37																																		
23 S.26																																		
26 S.143																																		
Timothy																																		
6 Potential *S* strain (early June-gap fodder)																																		
6 Scottish																																		
6 American																																		
7 S.50																																		
18 S.51																																		
26 S.48																																		
4 Potential *S* strain (late June - gap fodder)																																		
Meadow fescue																																		
21*American																																		
23*Danish																																		
25* S.215																																		
1* S.53																																		
Tall fescue																																		
3* S.170																																		
6* Alta																																		
Red fescue																																		
8* Danish																																		
10* S.59																																		

*Estimated in relation to emergence data collected 1955

having a range of about one month in their emergence dates, were represented by several clonal units, (A. R. Beddows and D. E. Stephens).

The effect of increasing altitude in delaying the date of inflorescence emergence in early- and late-heading material, is shown below for four stations at four altitudes. The date of emergence for the earliest plants, 7 May, is recorded as unity, and the relative differences at the various centres have been correspondingly adjusted. It will be observed that even for genetically-identical material the date when the inflorescences come into view is delayed as altitude increases.

	Ft. above sea level				
Plants	24	422	452	950	
Early heading	1	4	7	26	days later to emerge
Fairly late heading	19	24	30	39	,, ,, ,,
Very late heading	37	44	46	–	,, ,, ,,

The relative dates of anthesis for the same plants at the same centres are indicated below, the date for the early plant is recorded as unity.

	Ft. above sea level				
Plants	24	422	452	950	
Early	1	5	10	21	days later to flower
Fairly late	18	20	24	34	,, ,, ,,
Very late	29	33	37	–	,, ,, ,,

The trend of the dates for anthesis commencement also shows a delay comparable with that for emergence, but the days of delay were rather fewer for the late plants.

Other species now being studied are *Festuca pratensis, F. arundinacea, Dactylis glomerata* and *Arrhenatherum elatius*.

Date of sowing in relation to the severity of rust infection in timothy

The influence of date of sowing on the degree of rust infection in eight timothy strains has been investigated by Miss Margaret Fairley (now Mrs. A. M. M. Rees, British West Indies). Five of the strains under test were Station-bred, two others, Scotia and Kämpe II, had been developed respectively in Scotland and Sweden, and one was an American commercial timothy. The strains were sown at fortnightly intervals during the spring and summer of two

successive years ; a technique of inoculating rust spores into highly susceptible plants interspaced among the strains was used in order to ensure that epidemic conditions prevailed. Particulars of the degree of rust infection were collected throughout the sowing and first harvest years. The evidence obtained in the autumn of the year of sowing suggests that later sowing reduces the severity of rust attack in American, Scotia and Kämpe II timothy, and enabled these relatively susceptible strains to escape the main rust epidemic. In the following year, however, these relatively rust-free plants in most cases became badly infected, showing that late sowing is not a substitute for resistance.

The Aberystwyth strains were all highly resistant throughout and were not affected in either season by date of sowing.

The influence of date of sowing on heading behaviour in timothy

The development of inflorescences under different conditions was studied by Dr. Betty Cocks. A series of strains was sown at various dates ranging from 15 March to 10 August, 1953. Heading behaviour was compared in the seedling year and in the following year after overwintering. Data were collected on the number of heading and non-heading plants in each strain in the year of sowing, on the date of emergence for each plant in the sowing and the first harvest years, and on the total number of heads produced in each year.

In the first harvest year, a well-defined sequence of mean dates of head emergence was obtained, with a difference of about 4 weeks between the earliest and latest heading strains.

Heads were produced in the autumn of the sowing year by some plants of all strains and for all sowings other than the latest. More plants came into head in the early than in the late strains, except for S.50 (*Ph. nodosum*), the diploid strain, which, though normally early heading, had the greatest number of non-heading plants throughout. In all the strains the proportion of plants heading decreased at later sowing dates. Plants of timothy, unlike many of the north temperate perennial grasses, appear to initiate heads readily in the absence of exposure to low temperature. The sequence of heading dates in the sowing year differed from that obtained after overwintering and the range in heading dates of plants within any strain was very much greater, being between 41 and 75 days, as compared with between 14 and 23 days in the first harvest year.

In overwintered plants the sequence of heading dates among strains of timothy has been shown to depend on differences in

photoperiod requirement. The different sequence in the seeding year suggests that photoperiod is not the limiting factor. In all but the earliest sowings, day-length exceeded the minimum for all strains or did so shortly after the time of sowing. In an extension of this experiment the effects of different periods of vernalization on heading behaviour in the year of sowing are being investigated. The investigation of the number of inflorescences produced per plant in the seeding year has shown that they decrease progressively with delay in date of sowing. The effect of lateness of sowing was carried over into the following year for all sowings after mid-May. This indicates the necessity of early sowing if a good seed crop is desired the following year.

Meteorological conditions in relation to anthesis

The time of day at which flowering takes place in the grasses varies from one species to another and from day to day according to weather conditions; in *Lolium perenne* and *L. italicum* it normally occurs in the late morning. An investigation into the relationship between meteorological conditions and the daily rhythm of anthesis in these two species was started by Dr. Betty Cocks. It was found that in perennial ryegrass anthesis commenced at approximately 11 a.m. (B.S.T.) on days when the temperature rises rapidly between 7 a.m. and mid-day with a corresponding fall in relative humidity. Flowering was at a maximum between 12 .00 and 1 p.m., and was usually completed by about 2.30 p.m. This behaviour was found on days in which the maximum shade temperature in the early afternoon ranged from 68° to 74°F., and minimum relative humidity was between 40 and 55%. If the temperature remained low, or was slow to rise, flowering commenced at the same time, but then continued until about 5 p.m. and the period of maximum anthesis was less sharply defined. This occurred on days with a maximum shade temperature of 58°F. to 68°F. and a minimum relative humidity of 60 to 70%.

Flowering did not take place when rain continued throughout the day, but if the rain ceased soon after the usual time of flowering slight intermittent anthesis occurred even under conditions of high humidity.

In Italian ryegrass anthesis showed the same trends as in perennial ryegrass, but continued over a longer period. On fine, warm days it commenced at 9.30 a.m. and continued until between 4.30 p.m. and 6.30 p.m. When a marked rise in temperature occurred during the morning accompanied by a drop in humidity, flowering

was largely completed by 1.0 or 2.0 p.m. If the temperature rise was less marked and did not reach its maximum until late afternoon the zenith of flowering was also delayed until between 2.30 and 4 p.m.

The investigation is being continued and extended to other species. The time and period of pollen liberation is also of interest to those studying fluctuation of the concentration of atmospheric pollen in its relation to hay fever.

SHOOT MORPHOLOGY IN VARIOUS *Gramineae*

Observations of the species *Glyceria declinata, Poa annua* and *Phleum pratense* by Martin Borrill showed a characteristic pattern of leaf size along the shoot. Leaf-blade length and width increased together to a maximum value, thereafter leaf-blade length decreased to the flag-leaf, whilst leaf width remained relatively constant. Leaf morphology was therefore studied in relation to the initiation of the inflorescence at the shoot apex. The wheat Squarehead's Master was used as experimental material, because of its genetical uniformity. The following treatments were given :—

Low temperature exposure (days)	*Weeks to head*	*Photoperiod*
0	20.0	Continuous
14	18.0	,,
28	13.0	,,
42	12.6	,,
56	11.0	,,
70	10.5	,,

Thirty seedlings were used in each treatment ; on 15 the leaves were measured, and on the remaining 15, apex dissection and epidermal cell-length measurements were carried out. The data show that in every treatment the leaf-length increased to a peak value and then decreased to the flag-leaf. Inflorescence initiation at the shoot apex occurred when the longest leaf was appearing, and the trend of leaf length is paralleled by that for cell length.

This suggests that leaf-length is related to cell-length rather than to cell number, and that inflorescence initiation influences the size of the leaves which expand subsequently.

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PLANT GENETICS (GRASSES)

By J. P. Cooper

The main project of the work in this Section is the study of genetic and physiological differences between species and strains of herbage grasses which are responsible for their variation in field performance. Most of these differences show continuous variation, and many are strongly influenced by environmental conditions.

Most attention has been given to the timing and extent of inflorescence development, since this controls the duration of the life-cycle and the season of flowering, characters which are of great agronomic importance. In 1955 studies were started on the rate of leaf and tiller production in the seedling stage, its genetic and environmental control, and its relation to seasonal productivity.

This work has involved three stages ; firstly, the establishment of standard field and greenhouse techniques for measuring developmental responses, and the use of these techniques to detect differences between species and strains ; secondly, a study of the genetic control of these differences ; and, thirdly, an investigation of the genetic structure of populations of herbage grasses, paying special attention to the balance between free and potential variation, and to the rate at which potential variation is released for selection.

Pilot studies on *Lolium*

A comparative study of the flowering requirements of species and strains of *Lolium* from different climatic and agronomic origins was started in the Grass Breeding Section of the Station in 1948. The work was continued in the Department of Agricultural Botany, University of Reading, from 1950 to 1954, and resumed at Aberystwyth when the present Section was set up in 1954.

The main developmental responses proved to be a winter requirement for short-day and/or low temperature, followed by a response to long photoperiod in the spring or early summer. After ear initiation had occurred under appropriate photoperiod, the rate of inflorescence development was controlled largely by spring temperature.

The environmental requirements for each strain were closely related to its climatic origin or agronomic performance. The winter requirement appeared to control the duration of the life-cycle, being highly correlated with the annual, biennial or perennial habit. The summer annual Westernwolths ryegrass and the annual weed

species, *L. remotum* and *L. temulentum*, had no winter requirement and would head rapidly after a late spring sowing. In the winter annual Wimmera ryegrass heading could occur after a spring sowing, but it was accelerated by winter exposure, and in the biennial Italian ryegrass several plants failed to head without such exposure. In the strains of perennial ryegrass, nearly all plants had an obligatory winter requirement, the persistent pasture types (Kent, S.23, S.101) requiring a longer exposure than did the shorter-lived Irish perennial ryegrass.

The date of heading in the spring after overwintering outdoors is controlled by response to long photoperiods. All the strains tested were long-day in their response, but the critical photoperiod varied with the strain, being lower (10–12 hr.) in the early-flowering material, Wimmera, Irish, S.24, and higher (13–14 hr.) in the late-flowering S.23 and S.101, with Italian ryegrass intermediate.

This early work also gave some information on the genetic structure of these outbreeding strains, and on the effect of the breeding system on the storage of genetic variation.

Although each outbreeding population of the *L. rigidum/italicum/perenne* group headed fairly uniformly after an autumn sowing outdoors, i.e., the conditions for which it had been selected, under other photoperiods or after threshold winter exposures, considerable genetic variation in flowering responses became apparent. Similar behaviour was shown by the progenies from crossing two parents of similar phenotype, and even from selfing one individual. Much genetic variation is evidently carried in these outbreeding populations, both between individuals and in the heterozygous condition within individuals. No such variation was detected within single lines of the self-pollinated species, *L. remotum* and *L. temulentum* although differences may exist between lines in the same local population.

Transplant studies

It proved possible to relate local and seasonal differences in ear emergence of perennial ryegrass to local differences in photoperiod and spring temperature within the British Isles.

Through the generous assistance of many observers, the heading behaviour of twelve early-, medium- and late-flowering clones of ryegrass was recorded at several locations in the British Isles, covering a range of latitude and spring temperature. The records for the two years 1950 and 1951, show a gradient from early flowering in the south-west (Scilly and Cornwall) to late flowering in the

north-east (Aberdeen and Shetland), but this trend is modified by altitude. Although ear emergence is strongly influenced by locality and season, the relative order of early-, medium-, and late-flowering strains remains the same. The genetic difference between the early and late strains is of the same order as the environmental variation between the climatic extremes, Scilly and Shetland.

The effects of both locality and season on ear emergence could be explained in terms of spring temperature after the critical photoperiod had been reached. In the early-flowering strains (Irish, New Zealand, S.24) ear initiation occurs in early March and it is March and April temperatures which are important. In the later flowering S.23 and S.101, initiation does not occur until early April, and April and May temperatures are concerned. Once the critical photoperiod has been reached, response to temperature is similar in both the early and the late-flowering strains.

Standard greenhouse tests for flowering responses

Following the comparative study of the flowering responses of species and strains of *Lolium*, it was decided to try to establish standard laboratory and greenhouse tests for such responses, and then use the tests for the rapid analysis of populations and their classification into different agronomic groups. In the development of the tests at Reading during 1950–54, work was concentrated on the cereals, wheat, oats and barley, particularly the geographical collection of wheat varieties made by the late Professor J. Percival. These have the advantage of providing uniform genetic lines for comparative study.

The timing of inflorescence development was studied by the dissection of the shoot apex in several lines of cereals under a range of temperatures and photoperiods. The rate of leaf appearance was linear for any shoot and was unaffected by the initiation of spikelet buds on that shoot. The elongation of the shoot apex was exponential, being gradual during vegetative growth, but increasing at spikelet initiation. In cereals, the elongation of internodes began only at the late spikelet bud stage, and progressed stepwise, one internode beginning to elongate as the preceding one ceased. The general pattern of inflorescence development was similar in all material, but differences occurred between varieties in the time at which spikelets were initiated and in the rate of subsequent elongation. The leaf number before heading on the main shoot was used as a quantitative measure of inflorescence development. It records the physiologic age at which spikelet initiation occurs and is only

slightly affected by temperature fluctuations between 50°F. and 70°F.

In the tests for response to low temperature induction, the germinating seeds are exposed to low temperatures, 0–5°C. (32–41°F.) for varying lengths of time and then transferred to long-day or continuous light. The temperature immediately after planting is kept at 50–60°F. to avoid further vernalisation or devernalisation. Photoperiod is optimum for ear initiation and elongation, and the rapidity of heading is a measure of response to low temperature.

The usual method of testing for response to photoperiod under a range of constant photoperiods has the disadvantage that in short days the plants may head slowly or not at all, thus increasing the demand for time and labour. A more rapid turnover can be obtained by exposing the seedlings to differential photoperiods from germination onwards, and transferring at a series of dates to long-day or continuous light. The leaf numbers at transfer and before heading are recorded, from which the inductive effects of the initial photoperiods can be calculated.

Later work has shown that short-day induction is an important component of the winter requirement in *Lolium* and in other grasses and standard tests are now being established for response to this factor, both alone and in combination with low temperature.

Adequate equipment is now available for these developmental analyses. Supplementary lighting, using filament bulbs, sufficient for 7,000 seedlings, was installed in the greenhouse in September 1955, and photoperiod rooms with supplementary lighting were completed in August 1956. A refrigerator for the cold treatment of seeds and seedlings was acquired in October 1955, and this has now been fitted with interior lighting for combined low temperature and photoperiod treatments.

Lolium. The use of these standard tests has extended the earlier results on population differences in *Lolium.* In autumn 1955 a range of annual, biennial and perennial populations of *Lolium* was tested for response to low temperature induction.

All the annual strains produced heads eventually without cold treatment, but different agronomic groups could readily be distinguished. The samples of Westernwolths ryegrass headed rapidly after 4–6 leaves, but Wimmera showed ranges from 5–22 leaves with means about 11 or 12. The annual ryegrasses from Oregon and from South America were intermediate in behaviour between

Wimmera and Westernwolths ryegrasses. In samples of Italian ryegrass from New Zealand and Lombardy, Italy, all the seedlings produced heads without cold treatment although heading was accelerated by low temperature, but in the strains of Italian from northwest Europe, only 20–50% of the plants produced heads without low temperature, and the proportion was lower still in Short Rotation H1, and S.22 Italian ryegrass. Few plants of perennial ryegrass headed without cold treatment.

A better separation of the biennials and perennials was provided by cold treatment for 5 weeks; nearly all plants of the Italian strains headed, but in Short Rotation only 40–60% did so. The perennials were separated into the short-duration types, such as Irish and Devon Eaver, in which up to 30% of the plants headed, and the long-duration strains, such as S.24, S.23, S.101 and Kent, in which very few heads appeared.

It is evidently possible to separate populations of *Lolium* into different agronomic groups by the above greenhouse technique, which may therefore be of value for the identification and testing of seed samples, or the preliminary screening of breeding material.

Supplementary lighting in the greenhouse has also been used to follow the changes under selection in one population of Wimmera ryegrass. The parent population and lines selected over three generations for early and late heading after a spring sowing were grown under continuous light without previous cold treatment. The parent population showed a range from 5 to 18 leaves before heading with a mean of 10.9 and a variance of 10.5. The progeny lines showed a rapid response to selection and by the third generation the earliest and latest lines had mean leaf numbers of 8.2 and 15.4 respectively. Although the genetic variation within the lines decreased during selection an appreciable quantity remained after three generations.

Even so, the tests are still rather lengthy, especially for perennial strains. Irish perennial ryegrass requires 10 weeks' cold treatment for complete induction, and Kent and S.23 rather more. Preliminary results indicate that a short-day pre-treatment also has an accelerating effect on heading in *Lolium*, and techniques for treating germinating seed and young seedlings with combined short-day and low temperature are being developed in collaboration with Professor M. L. Peterson, Univ. of California. It is hoped that such techniques will make it possible to speed up the testing of perennial strains of ryegrass.

Phleum. A pilot range of strains of timothy was tested for

response to low temperature and photoperiod during summer 1955. Seeds were given 0, 6, and 12 weeks' cold treatment, and as no controlled lighting was then available the different photoperiods were provided by a range of sowing dates in spring and early summer. This work was carried out in collaboration with Dr. Betty Cocks of the Grass Breeding Section.

As was expected from their field behaviour, none of the strains tested showed any requirement for low temperature or short-day induction. They did, however, vary in their response to photoperiod, and in their rapidity of heading even when photoperiod was optimum. The differences in heading behaviour were related to the field performance of the strains concerned, the strains selected for leafiness showing higher values: the highest leaf number before heading (14.6) was given by the pasture strain S.50, and the lowest (8.5) by American commercial timothy.

In autumn 1955, therefore, when supplementary lighting became available, a range of populations, including commercial and bred strains from North America, Britain and Scandinavia, was grown without previous cold treatment under continuous light in the greenhouse.

Flowering was most rapid in the North American strains which began to produce heads after 6–7 leaves, and these were followed by the British and Scandinavian material in that order. The diploid pasture strain S.50 was last of all, hardly any plants forming heads. Heading was quite normal during September and October, but it had ceased completely by the beginning of November although continuous light was still applied, and in those seedlings which remained the main shoot began to elongate and often became stoloniferous.

In later sowings made in February and June, 1956, the same geographical grouping of strains was apparent, but even with the increased total light intensity the main shoot became stoloniferous in some plants of the British strains and in much of the Scandinavian material. In the February sowings, the main shoots of some plants remained stoloniferous, but heads were formed on the axillary tillers. Evidently once a shoot has become stoloniferous it will not form heads, even if transferred to more favourable conditions.

Although strains of timothy can evidently be separated into different geographical groups by the use of supplementary lighting, their exact requirements for light intensity, spectral composition and temperature are far from clear and need further investigation.

In *Phleum*, unlike *Lolium*, the perennial habit is not associated

with a requirement for low temperature and/or short day before flowering. On the other hand, the photoperiodic requirements for the British strains of *Phleum* (15–16 hr.) are higher than those for *Lolium* (10–14 hr.) and there is evidence in *Phleum* that yet another factor is involved in inflorescence development.

Dactylis. Most populations of *Dactylis glomerata* from north-west Europe possess a winter requirement before heading in the field, but cold treatment of the germinating seed for 12 weeks prior to sowing was not sufficient to induce heading, and the effect of short-day induction of the young seedlings is now being studied. Techniques for providing short-day exposure *before* and *during* low temperature treatment are also under investigation. When a standard method for satisfying the winter requirement of *Dactylis* has been established, the comparative study of different climatic and agronomic populations will be started.

Cereals and annual weed grasses. During the establishment of the standard greenhouse tests for developmental responses at Reading in 1950–54, a number of cereals and annual weed grasses was tested for response to low temperature induction. The cereals included wheats from Europe, North America, India and the Mediterranean region, and European barley and oat varieties. Response to low temperature induction was obtained in only one ecological group, the winter wheats from north-west Europe. The other cereals, including the winter oat varieties Bountiful, Picton, S.147 and S.172, headed rapidly without any cold treatment. Constant differences in leaf number before heading occurred even among spring varieties, but these differences were small and could not be correlated with any particular climatic or agronomic factor. It was possible in these tests to detect rogues within stocks of a single cereal variety.

Most of the annual grasses tested were either weeds of arable crops or casuals of disturbed ground and waste places. Many of these, such as *Aegilops ovata, Briza maxima, B.minor, Desmazeria sicula, Hordeum jubatum, Lolium loliaceum, Poa annua,* and some samples of *Lolium remotum, L. temulentum* and *Triticum aegilopoides,* proved to be summer annuals showing no response to low temperature induction, while others, including *Anthoxanthum puelii, Phalaris canariensis, P.minor,* and some samples of *Lolium temulentum* and *Triticum aegilopoides* were winter annuals with a quantitative response to low temperature.

All the above results indicate the potential value of the present greenhouse tests for varietal identification and classification, and

also for the study of genetic variation in populations and the changes occurring under selection.

Genetic control of flowering responses

The genetic control of flowering responses in *Lolium* has been studied by crossing parents from extreme populations of the outbreeding group *L. rigidum*, *L. italicum*, *L. perenne*, and growing parents, F_1, F_2, and backcross progenies in such a range of environments as would separate the two developmental responses, winter requirement and response to photoperiod. Both these responses are polygenically controlled, no main gene differences being apparent. This makes possible continuous variation in both components of inflorescence development, and, therefore, close adaptation to local environment. It also implies that a similar phenotype can be produced by several different combinations of genes. The parent plants from all the outbreeding populations are heterozygous for genes controlling heading responses. Both winter requirement and response to photoperiod behave as threshold characters ; for each genotype there may exist a critical photoperiod or critical winter exposure without which no heading can occur.

The genetic control of flowering behaviour has also been studied by crossing plants from within the same population, and calculating the heritability of flowering behaviour from the regression of the progeny on the mid-parent value. In crosses made within Irish, Devon Eaver and Kent ryegrasses, the heritability of response to photoperiod, as measured by date of ear emergence in the spring, was high ($\geqslant 70\%$) in 1955 and 1956. Winter requirement also was highly heritable. There is, however, a tendency for the progenies from extreme parents to regress towards the mean for the population, suggesting some form of genetic homeostasis. Although the heritability of these responses is high, much potential variation is carried within individuals and released in the next generation. The variances of progenies from selfing and crossing individuals are of the same order as those of the original populations, while the distributions of progenies from extreme parents transgress those of the original populations in both directions. The variances of selfings are significantly higher than those of the corresponding single crosses. Furthermore, the mean values of ear emergence for selfings were significantly later (about 6 days) than for the corresponding crosses, indicating some degree of heterosis for this character.

Genetic structure of populations

The early population studies on *Lolium* had shown that considerable genetic variation in flowering responses was carried both between plants and also within plants in the heterozygous condition.

A long-term selection experiment was, therefore, started in autumn 1953, to assess the free and potential variation in developmental responses within populations of *Lolium*, and its rate of release under selection. The characters chosen for study were, firstly, the date of ear emergence in the spring after overwintering outdoors (a measure of response to photoperiod), and, secondly, the extent of head production after a spring sowing (a measure of winter requirement for short-day and/or low temperature). The three populations chosen as initial material were: (i) the early-flowering winter-annual Wimmera ryegrass, (ii) the early-flowering Irish perennial ryegrass, and (iii) the late-flowering Kent indigenous perennial ryegrass. The agronomic behaviour and past selection history of these strains are well documented.

Appropriate breeding systems were adopted to assess the potential variation carried within one plant, within two, and within a group of four, and also to study the effect of different degrees of inbreeding on vigour and on the depletion of genetic variation.

Response to photoperiod. In the first year, 1954, the four earliest and the four latest plants were selected from samples of Wimmera, Irish and Kent ryegrasses and the following breeding systems adopted for each group: (a) all four plants allowed to intercross and harvested in bulk, (b) the plants within each group crossed in pairs, (c) each plant selfed.

In the next generation, early and late selection lines were established from each progeny, and the same breeding systems continued, except that the lines derived from selfing were continued by pair-crossing also.

In autumn 1955, the original populations and first and second generation progenies, together with clonal material of all parents (for the perennial strains) were planted out in the field and date of ear emergence recorded in spring 1956.

The clonal parents show a high correlation between the dates of ear emergence in two or three consecutive years; the clonal variance of a single individual in one year is about 4 days, so the difference between two seedlings must exceed 5-6 days to be significant. Response to selection continued in all lines and under all breeding systems; in the selfed material, however, self-sterility

and inbreeding depression made it impossible to maintain all lines. There was little difference in response between the lines derived from one, two or four parents, and the genetic variance of the progenies showed no appreciable decrease from that of the original populations. The range between the earliest and latest plants derived from each initial group was of the order of 14-28 days, and the extreme lines of both Irish and Kent had been carried well outside the range of the original populations. There is evidently considerable potential genetic variation for response to photoperiod stored within single individuals, in spite of the high average heritability of this character.

These lines were continued in summer 1956 following the original breeding systems, but in addition, fourway crosses were made between parents from appropriate pair and single plant progenies to overcome the effects of inbreeding, while maintaining the direction of selection. The original populations and progenies from three generations of selection were planted in the field in autumn 1956, together with clonal material of parents of all generations, totalling about 7,500 plants. Records will be taken in spring 1957 on the date of ear emergence and also on plant vigour and ear conformation.

Winter requirement. The use of heading behaviour after a spring sowing as a measure of winter requirement involves a generation-time of two years, and progress is, therefore, slow in this experiment. Parents selected in summer and autumn 1955 were brought into the greenhouse under continuous light in early spring 1956 and crosses were made to provide second generation progenies for field testing. These will be sown out in spring 1957 and their heading behaviour recorded.

Original populations of Kent and Irish ryegrasses, and the first and second generation selection lines are also being tested for winter requirement under standard greenhouse conditions. It is hoped to be able to correlate their response to this controlled short-day and low temperature treatment with their heading behaviour after a spring sowing in the field.

Ear conformation. In summer 1956, a biometrical study of ear conformation was begun on material of *Lolium perenne* from the long-term selection experiment. Its aim was to measure the variation in ear characters between and within the original populations of Kent and Irish ryegrasses, to detect any correlated response to selection for flowering date, and to assess the effects of inbreeding on ear conformation. The measurements recorded included lengths

of culm and spike, number of spikelets, spike density, and the length and density of a standard spikelet.

Significant differences were detected between the Kent and Irish ryegrasses in length of culm and number of spikelets, but not in the other characters. While spike length was highly correlated with number of spikelets, and spikelet length with number of florets, significant differences in both spike and spikelet densities occurred ; and within each of the original populations, spike density was highly correlated with date of ear emergence. The data also suggest possible introgression from an early-flowering population into the Kent ryegrass.

There was no significant correlation between culm length and either spike length or date of ear emergence, between number of spikelets and number of florets, between spike density and spikelet density, or between the length of the spikelet and the length of the empty glume.

The heritability of all measurements was calculated from parent-progeny regressions in the first-generation families. Culm length, spike length, number of spikelets, density of the spike and length of the empty glume proved to be highly heritable, but most measurements showed pronounced inbreeding depression.

Selection for early or late ear emergence has produced no correlated response in the number of spikelets, but culm length and spike density seem to be affected, the late lines having significantly shorter culms and denser spikes.

The same measurements will be recorded on a wider range of material next summer.

Leaf and bud development

In the early studies on species and strains of *Lolium*, significant differences were found between and within populations in the rate of leaf production and in the proportion of axillary buds which formed tillers, though the differences were not so marked as those in inflorescence development.

In autumn 1955, it was possible to extend these studies, when Mr. A. S. Patel of the Institute of Agriculture, Anand, India, a post-graduate research worker, began a comparison of leaf and bud development in *Lolium* and *Phleum*. The aim of this work is to compare the rate of leaf and tiller development in the seedling stage in different strains under standard greenhouse conditions, and to detect any correlation between these seedling differences and the yield and seasonal production of mature spaced plants in the field.

Five strains of *Lolium* (Westernwolths, Italian, Irish, Kent and S.23) and five of *Phleum* (Scottish, S.51, S.48, Bd 2502, and S.50) were sown at two-monthly intervals during 1955–56 and the rates of leaf appearance and of tillering were recorded for each seedling. Crosses to determine the heritability of the rates of leaf and tiller appearance were made in summer 1956, and the remaining seedlings were put out in the field as spaced plants for cutting treatments in 1957.

The same strains were also grown under two photoperiods, natural day and continuous light, with and without low temperature induction, during winter 1955–56. Records of leaf and tiller development were taken, the seedlings were harvested at the 12th–14th leaf stage, and the total number of leaves, tillers and crown roots was counted, the fresh and dry weight being recorded for each plant.

In all treatments the rate of leaf production on the main shoot is linear, but varies considerably with species and strain and with sowing date. In *Lolium*, leaf appearance is most rapid in Westernwolths and Italian ryegrass, while in *Phleum*, Scottish timothy usually produces leaves most quickly. In the autumn and winter sowings, the ryegrasses produce leaves faster than the timothies, but in the spring and summer sowings there is little difference between the two species. The time taken for each new leaf to appear on the main shoot varies with sowing date, being 4–6 days in May and July, but as long as 9–11 days in the November and January sowings.

Since each tiller arises as a bud in the axil of a leaf, the potential rate of tillering depends on the rate of leaf appearance. The actual number of tillers present, however, is greatly influenced by the node at which tillering first begins, and this varies with species and strain, and with sowing date. In *Phleum*, the coleoptile bud never develops into a tiller, the first leaf bud rarely does so and regular tillering does not usually begin until the third or fourth leaf axil. The pasture strains, Bd 2502 and S.50, have the highest proportion of tillers at the basal nodes, and Scottish the lowest. In *Lolium*, on the other hand, particularly in Westernwolths and Italian ryegrass, a tiller sometimes develops from the axil of the coleoptile, and very often from the first leaf axil. The development of basal tillers is most pronounced in the spring and summer sowings and least in the autumn and winter.

The time lag between the appearance of a leaf and of the tiller in its axil also varies with the species and strain ; in *Lolium*, a tiller usually appears as the next leaf but one is elongating, but in

Phleum, not till much later. Since leaf and tiller production on each shoot are linear, total leaf and tiller production are exponential, until competition becomes limiting or heading occurs.

In the seedlings harvested at the 12–14th leaf stage, the total numbers of leaves, of tillers, and of crown roots were highly correlated within both the ryegrass and timothy strains, but the timothies had a smaller proportion of tillers to leaves, and of crown roots to leaves. Methods are being devised for estimating the dry weight of a seedling from leaf and tiller measurements ; it is hoped that this will be of value in detecting any correlation between the rate of leaf and tiller development in the seedling and the forage production of the mature plant.

Single gene differences in *Lolium*

Although most of the agronomic characters under study show polygenic control, a collection is being made of single gene differences in *Lolium*. These are of value both in the study of the developmental effects of individual alleles, and also as genetic markers in population studies.

The developmental effects of the following single gene differences are under study.

Dwarf. This type, which is recessive to normal, was first observed by T. J. Jenkin among the inbred progeny of a plant of Ayrshire perennial ryegrass. The rate of elongation of leaf blade and sheath is severely decreased, resulting in the formation of a small dark-green rosette rarely more than 5 cm. in diameter. This genetic dwarf can be brought within the normal phenotypic range by treatment with gibberellic acid.

Broadrib. This type, which is recessive to normal, was first found by T. J. Jenkin among the inbred progeny of one plant of *L. perenne* and a recessive allele with similar effects has now been found in one of the Irish parents of the selection experiment. Both seedling and adult leaves are broader and shorter than in the normal with prominent ribbing on the upper surface. The inflorescence is rather compressed and very rigid. This type cannot be converted to the normal phenotype by gibberellic acid.

" Shaving-brush." This type first appeared in the progeny from selfing a plant of *L. perenne* from old pastures in Leicestershire. The leaves are narrower and paler green than in the normal, and the habit of growth is very tufted. Ear emergence is considerably delayed.

Roughness of stem. Roughness of the stem occurs in most

plants of Wimmera ryegrass, and occasionally in Irish, Devon Eaver and Kent. It appears to be controlled by a single gene difference, rough stem being dominant.

Brittle rachis. Occasional plants of Wimmera ryegrass have been found in which the rachis of the spike is brittle and disarticulates when the grain is ripe. The brittle rachis is recessive to the usual non-shattering form. It has not been recorded in perennial ryegrass.

Oblique ligule. One of the Irish parents of the selection experiment carries a recessive allele which, when homozygous, results in a very faint and oblique ligule on the flag leaf, with no visible boundary between blade and sheath on the underside of the leaf.

Pallid. This allele has appeared in breeding material of early-flowering *L. perenne.* It is recessive to normal, and gives a pale leaden-green colour to the plant from the fourth leaf stage onwards, accompanied by loss of vigour.

The linkage relations of these main genes with each other, and also with single genes controlling anthocyanin production, chlorophyll deficiency, and fluorescence of the seedling roots are being studied.

In addition, the frequency of these major genes in different populations, and their distribution in successive generations of the selection experiment, are being recorded.

Publications

Publications from 1950–1955 relate to work done in the Grass Breeding Section

Cooper. J. P. 1950. Day-length and head formation in the ryegrasses. *J. Brit. Grassl. Soc.* 5. 105–112.

Cooper, J. P. 1950. Evolution of temperature and photoperiodic requirements in the genus *Lolium. Advance Sci., Lond.* 7. p. 356. Abstract of paper read to British Association for the Advancement of Science.

Cooper, J. P. 1951. Studies on growth and development in *Lolium.* II. Pattern of bud development of the shoot apex and its ecological significance. *J. Ecol.* 39. 228–270.

Cooper, J. P. 1952. Studies on growth and development in *Lolium.* III. Influence of season and latitude on ear emergence. *J. Ecol.* 40. 352–379.

Cooper, J. P. and Money-Kyrle, A. F. 1952. Inflorescence development in *Lolium* during the Arctic summer. *Nature, Lond.* 169. p. 158.

COOPER, J. P. 1953. Genetic and environmental control of inflorescence development in *Lolium*. Ph.D. thesis Reading. Unpublished.

COOPER, J. P. 1953. Local climate and flowering in ryegrass. *J. Ecol.* 41. p. 410. Abstract of paper read to Easter Meeting 1952 of British Ecological Society.

COOPER, J. P. 1953. Genetic control of inflorescence development in *Lolium*. *Heredity* 7. p. 152. Abstract of paper read to November 1952 Meeting of Genetical Society.

COOPER, J. P. 1954. Studies on growth and development in *Lolium*. IV. Genetic control of heading responses in local populations. *J. Ecol.* 42. 522–556.

COOPER, J. P. 1954. The developmental analysis of local populations in the cereals and herbage grasses. *Rep. and Comm. Eighth int. bot. Congr.* Paris. Section II. 356–358.

COOPER, J. P. 1955. Selection and population structure in *Lolium*. *Heredity* 9. p. 418. Abstract of paper read to Summer Meeting of Genetical Society.

COOPER, J. P. 1956. A rapid technique for strain identification in the ryegrasses. *J. Brit. Grassl. Soc.* 11, 42–47.

COOPER, J. P. 1956. Developmental analysis of populations in the cereals and herbage grasses. I. Methods and techniques. *J. agric. Sci.* 47. 262–279.

LEGUME BREEDING

By W. Ellis Davies

Up to the year 1933 the work of R. D. Williams had been concerned mainly with surveying the range of variation available in the legumes. The potentiality of strains, varieties and populations from all parts of the world was studied with the object of determining the most favourable material for use in a breeding programme. The biology of these same legumes was also elucidated, and suitable new techniques adopted for dealing with largely outbreeding, self-sterile crops.

Early studies in breeding

Considerable progress in clover breeding was made between the years 1933 and 1939, and during the period four bred strains of clover were released to the Seed Industry ; they included two strains of white clover and two of red clover. S.100 white clover has been given considerable prominence in British agriculture, and S.184 white clover now competes with wild white clover. S.151 red clover is a medium-early-flowering type which has shown excellent adaptation in the west and north. More use could be made of this strain if its adaptation for these areas was more fully appreciated and more attention was given to its requirements for seed production ; the seed yields tend to be low when the stands are managed as for double-cut strains ; S.123 extra-late-flowering red clover based on the local strains Montgomery and Cornish Marl, is an improvement on these types. Since the war years of 1939–45, the acreages of late-flowering red clover, including S.123, grown for seed, have for various reasons declined in England and Wales.

Bred strains of lucerne have not been released to the industry although the S.205 strain is an improvement on Grimm, the variety on which its breeding was based. Since 1945 seed of some of the Flamande types has become available in this country ; these varieties have shown a considerable advance on the Grimm type in yield, earliness and disease resistance. Potential strains of *Lotus* and *Anthyllis* were produced but not marketed.

Some of the more basic work was concerned with the genetics of clover and was reported in a series of papers dealing with the inheritance of chlorophyll deficiencies[1], incompatibility[2], cyano-

[1] Williams, R. D. 1939. *J. Genet.* 37. 441–458 ; 459–482.
[2] Williams, R. D., and Silow, R. A. 1933. *J. Genet.* 27. 341–362.

genesis[1] and linkage groups[2]. Extensive information was collected on the frequency of *S* alleles occurring in red clover populations. One lot of 24 English late-flowering red clover plants was shown to have 41 different *S* alleles, 34 being represented once and seven twice[3]. Using this and further data, Bateman[4] was able to calculate that the probable number of *S* alleles in red clover populations was 212 with 5% limits of 115 and 442. Red clover was found to be extremely heterozygous, with about 5% of the plants heterozygous for chlorophyll deficiency, of which over 100 types were studied. Stem and leaf development, pubescence, leaf markings, anthocyanin development, and flower colour were also studied.

Progress was abruptly retarded by the outbreak of the Second World War, and much of the work was held in abeyance. R. D. Williams was seconded from the Station to Carmarthenshire War Agricultural Executive Committee and was able to devote only a small fraction of his time to his clover work at the Station. A further serious setback occurred with the sudden death of R. D. Williams in 1943 ; no other person at the Station fully conversant with the investigations was available to continue the work. This was the situation when Watkin Williams was appointed in charge of the Section in 1944. Several new lines of research were initiated during this period, but most of these came to fruition after Watkin Williams left in 1950.

The data on *S* alleles collected by R. D. Williams[3] were published and similar data were subsequently derived from studies of *Trifolium hybridum*. This species was also found to be highly self-sterile with cross-compatibility of the oppositional factor type. Pseudo-compatibility varied considerably even among plants of the same family, and types approaching full fertility appeared in the progenies tested. In most of the progenies studied the expression of pseudo-compatibility was shown to be under the direct control of *S* alleles whose numbers proved to be extensive (Williams, 1951).

The behaviour of lucerne and lucerne/grass mixtures was studied in several centres in Wales. With one exception, lucerne sown alone gave the best lucerne survival ; cocksfoot was generally found to be too aggressive. Ryegrass, timothy and meadow fescue, while causing

[1] Williams, R. D. 1939. *J. Genet.* 38. 357–365.
[2] Williams, R. D. 1937. *Rep. Fourth int. Grassl. Congr.* 238–251.
[3] Williams, Watkin, 1947. *J. Genet.* 48. 51–68 ; 69–79.
[4] Bateman, A. J. 1947. *Nature, Lond.* 160. p. 337.

WILLIAMS, Watkin, 1944. Control of buried viable weed seeds by means of boron. *Nature, Lond.* 154. 771–772.

WILLIAMS, WATKIN, 1947. Review : *Leguminous forage plants*, by D. H. Robinson. *Ann. appl. Biol.* 34. p. 470.

WILLIAMS, WATKIN, 1947. The germination and establishment of red clover under conditions of direct re-seeding. *J. Brit. Grassl. Soc.* 2. 30–44.

WILLIAMS, WATKIN, 1947. Genetics of red clover (*Trifolium pratense* L.) compatibility. II. (a) Homozygous self-sterile S_xS_x genotypes obtained as a result of pseudo-fertility ; (b) Self-fertility. (Data collected by the late R. D. Williams, M.Sc. ; presented and discussed by Watkin Williams, B.Sc.) *J. Genet.* 48. 51–69.

WILLIAMS, WATKIN, 1947. Genetics of red clover (*Trifolium pratense* L.) compatibility. III. The frequency of incompatibility *S* alleles in two non-pedigree populations of red clover. (Data collected by the late R. D. Williams, M.Sc. ; presented and discussed by Watkin Williams, B.Sc.) *J. Genet.* 48. 70–79.

WILLIAMS, WATKIN, 1948. Self- and cross-compatibility in alsike clover (*Trifolium hybridum* L.). M.Sc. thesis Wales. (Unpublished)

WILLIAMS, WATKIN, 1948. Report on Eighth int. Genetics Congr., Stockholm, Sweden, 7–14 July. Typescript.

some loss of lucerne, were not nearly so damaging in this respect (Williams, 1950a).

In 1948 A. J. H. Carr was appointed as breeder/mycologist with special reference to clover rot disease caused by *Sclerotinia trifoliorum*.

On the resignation of Watkin Williams, W. Ellis Davies was transferred from the Grass Breeding Section in October 1950 to take charge of the Legume Breeding Section.

The work of the Section is concerned mainly with the improvement of the three legumes, lucerne, red and white clovers. As time permits, other less important species are dealt with, e.g., sainfoin (*Onobrychis viciifolia*) and strawberry clover (*Trifolium fragiferum*). Apart from the immediate objectives in the breeding programme, more fundamental studies on fertility relationships and genetics, interspecific hybridization, selection techniques and plant pathogens are investigated.

Economic Breeding

White clover. One of the main projects in white clover breeding is the production of a new strain of a more robust character with larger leaves and longer petioles than the existing S.100 strain. It is felt that such a strain would compete more satisfactorily with grasses, especially for the production of silage, and grass for artificial drying. The shading effect of tall-growing grass herbage, which is accentuated by applications of nitrogen, is thought to be a major limiting factor in the growth of clover under these conditions. The variety used as a basis for this work was Ladino, and this programme was commenced in 1949. The growth of Ladino is outstandingly good in the seeding year under British conditions, but afterwards it declines severely and fails to persist. Slugs find it particularly palatable, presumably due to the low percentage of cyanogenetic plants found in this variety.

Since 1949 numerous F_1 families have been grown and these have generally been outstanding in vigour and leaf size. The F_2 progeny produced from selections of the best F_1 families has been nearer to the S.100 type in leaf size, but has given the expected variety of types. The first F_3 families were established in the summer of 1956 and it was desired to study them under conditions nearer to those in the sward. This was achieved by planting the seedlings 1 ft. apart in a plot 9 ft. x 9 ft. and oversowing with S.24 perennial ryegrass at 16 lb. per acre. The same families were also established as single plants 3 ft. apart, so that the data obtained from the two systems could be compared. The results in the seedling

year showed a good correlation between the intercultivated widely-spaced plants and the grazed plots.

Crosses were made between selections of the Ladino variety, but little progress was achieved.

A major problem in seed production of herbage strains is the authentication of seed. Up to the present, reliance has been placed on documentary evidence of the stocks sown and field inspection of the crops, but this procedure is not entirely satisfactory. It is possible, however, to make use of leaf markings on white clover for this purpose. The release of a new strain, S.100 " Nomark ", has now been authorised, and it should be a contribution towards easing this problem. It can be identified from other strains by the complete absence of leaf marks. Its agronomic properties, however, are very similar to those of the sister strain S.100 (Troughton, 1955a, 1955b). Absence of marking is a recessive character, so that the amount of crossing with marked types can be observed quite easily by growing-on the seed of the " Nomark " strain. A descriptive note appears on p. 167.

Red Clover. Similarly a " Nomark " strain has also been developed from re-selections in S.123 red clover; breeding material and sufficient seed may be available for agronomic testing in 1957. Provisional observations on single plants show that this strain is exceptionally persistent. A new peaked type of late-flowering red clover on which the tillers are always in a vertical plane instead of being very prostrate is being developed. The first selections of this type proved to be unstable in multiplication and further re-selection is taking place.

No work was done on the selection of double-cut red clover for improved productivity, as it was considered that resistance to clover rot was a basic requirement for such a type; progress on this work is reported under pathology.

Lucerne. It has been stated earlier that lucernes of the Grimm type were used extensively in the breeding programme before the value of the Flamande types became known. Part of the breeding material has been derived from plants of Grimm and Hungarian White Seal origin; the last selections from this material are now under agronomic test. In addition, crosses have been made between Du Puits and Rhizoma, and F_2 families are now under study. The latter variety is an interesting strain, and although it rarely creeps it is very leafy and contains many plants with yellowish flowers. It is thought that such a plant might succeed better under the high rainfall and acid soil conditions of the west. It has been crossed with

Du Puits in order to produce a more vigorous strain, with a longer growing season. Selections have also been made within well-defined French types, e.g., Flamande and Poitou, as a result of potentiality trials with strains of these types.

Polyploidy

Since 1950 Miss Alice M. Evans has been engaged on the production of polyploids in lucerne, red and white clovers. The techniques used have been described (Evans, 1955b); it was found that the best method was not the same for each species. Correlations of pollen-grain diameter and stomatal size with ploidy were found useful in accelerating the work.

Greatest progress in breeding has been made in red clover, where the polyploids are larger, more robust, and have thicker and fewer stems. So far the work has been confined to single plant studies, and many of the families have given superior yields to the diploid controls. Selections have been made of four distinct types based on yield, tillering, thickness of stems and time of flowering. Polyploid families have two important limitations at the present time—low seed-setting and greater susceptibility to drought. It is hoped that selection will effect improvements in these characteristics.

Few of the 64-chromosome white clover families have given increases in yield as single plants over S.100 used as control. Initial multiplication is being made of both red and white clover polyploids in order to have seed for agronomic testing. It will be possible to decide the potential value of tetraploids only after prolonged testing under a wide variety of conditions. Lucerne polyploids have not yet been under field test.

Potentiality Trials

Each year new plant material is kept under observation and tested to study its potentialities for breeding work. Seed samples of bred strains are received from all parts of the world for observation. Other material includes indigenous collections made by individuals.

White Clover. During the period under review the number of white clover lots studied in this way has been small. Ladino clover has figured largely in this material and the general results have been very unsatisfactory. This applies equally to Ladino from Italy and from U.S.A. The latter has generally tended to be smaller in leaf size and plant type than the Italian, but its agronomic performance has been the same.

Several lots of wild white clover collected by A. R. Beddows

from old pastures in England have proved to be remarkably uniform in type. The leaves were generally smaller than those of S.184 and growth was dense. The apparently excellent results obtained from a collection made in Normandy by Moses Griffith has suggested that there may be many more European ecotypes which could be useful in the breeding programme. Many such lots already in our possession were established in the field during 1956.

A cutting trial of eight white clover strains over a three-year period showed that the medium-leaved types gave higher yields than the small-leaved types S.184 and Kent. Differences between the medium-leaved strains, which included S.100, S.100 " Nomark ", Kersey, New Zealand Certified Mother and Permanent Pasture, were generally small. Ladino clover gave low yields and lacked persistency.

Lucerne. Several trials on lucerne varieties have been conducted, those of French origin generally giving the best results. Since a large proportion of the seed imported may come from this source, it is important to have information about the different types available. The most satisfactory is the Flamande type, which is generally superior in yield, establishment, length of growing season, aggressiveness and freedom from disease (Davies, 1954a). Du Puits is perhaps the best known of this type, and while its superiority may not be statistically significant, no other Flamande type tested has consistently outyielded it ; such varieties included Ormelong, Chartainvilliers, Flandria, W268, and the newer F.D.100, Orchésienne and Emeraude.

The Poitou lucernes, which include Marais de Luçon and Marais de Challans, have been fairly satisfactory but have given smaller yields than the Flamande group. Their stems are finer and the stands more leafy, but this may cause lodging under certain conditions.

Of the French varieties, Provence lucerne has proved to be the least satisfactory for British conditions, giving yields considerably less than the Flamande group and suffering much more from such limiting factors as boron deficiency and diseases. Seed of this type, however, is variable and some lots approach the Poitou type in performance. The Australian strain Hunter River has also given a poor result.

All the American strains studied have behaved like Grimm with a typical continental growth curve. Spring growth is late and there is generally little growth after a cut in September, the plants proceeding into the winter rosette condition. When cut twice these give

a yield only slightly less than Flamande, but under more frequent cutting the disparity is greater. Only 2–3% of Rhizoma plants were of the creeping type, compared with 25% of the material from Dr. Heinrichs, Saskatoon, Canada. The general vigour and aftermath growth, however, were very poor and this type will need considerable improvement before it can be of economic importance.

Sainfoin. A three-year trial of eight varieties was established in 1952. The data collected by Miss Alice Evans from drills in the third year showed that the common types gave the highest yields, whereas the Giant form thinned considerably. Eastern Counties Common appeared to be intermediate in persistence and flowering between the Giant on the one hand, and the Common varieties from Hampshire, Cotswold and Glamorgan on the other.

Technique studies

One of the more difficult tasks facing the herbage plant breeder is the assessment of progress. Data can be collected without difficulty from single plants, but the correlation between single plant and broadcast plot behaviour is not always apparent. In addition, the effect of the companion species and also of the grazing animal has to be borne in mind. Some attention has, therefore, been paid to this aspect of the work and trials have been devised to elucidate some of these relationships. The first trial was conducted by J. D. H. Reusch, Natal Agricultural Research Institute, Pietermaritzburg, a post-graduate research worker, in which four strains of lucerne were compared as single plants, in drills, broadcast, drills + a companion grass, broadcast + a companion grass. The results gave a significant strain × treatment interaction showing that all the strains did not give the same relative result under each treatment. This is clearly shown by the following yields of dry matter expressed in 100 lb. per acre :

	Du Puits	*S.*205	*Provence*
Broadcast	77.9	70.0	69.6
Drills	66.7	53.7	52.0
Single plants	45.3	44.4	27.0

The yield of S.205 and Provence was practically identical in the broadcast plots, but as single plants Provence was very inferior.

In turn S.205 and Du Puits single plants gave similar yields, but in the broadcast plots the latter was markedly superior. This confirms the impression that single plants are not necessarily a good guide to the performance of broadcast plots. As the main discrepancy appeared to be between single plants and other treatments, a new experiment was established in 1956 where smaller spacings were used, viz., 2 ft. × 1 ft. 6 ins. (control), 1 ft. × 1 ft., 6 ins. × 6 ins., 3 ins. x 3 ins., broadcast plot (control).

LUCERNE AGRONOMY (in collaboration with Dep. Agric. Chem., U.C.W.)

Studies have been carried out to learn more about the behaviour of the lucerne crop under relatively high rainfall conditions and acid, stony, soils. This information was necessary so that the possibilities of improvement could be assessed and the best material used. The first experiment (Davies R. O. *et al.* 1953, Davies W. E. and Davies R. O. 1956) compared the productivity of lucerne and lucerne/grass mixtures with a commonly used grass/clover mixture ; three cutting systems were imposed, viz., twice, three and four times. Marked differences in yield and subsequent performance were observed after the differential cutting treatments in the first harvest year. Over four years the highest yields of dry matter and crude protein were obtained after three cuts in the first harvest year, but this was not significantly superior to two cuts for dry matter and four cuts for crude protein.

Cocksfoot depressed the yield and plant counts of lucerne much more than ryegrass, while white clover contributed very little in a mixture with lucerne. As far as total yield of crude protein and dry matter was concerned, there was no advantage in associating grass with lucerne, but a higher weight of hay and a better nutritive ratio were obtained from the mixtures.

The difference in yield of nitrogen from the lucerne over the first two years compared with that from grass sown alone was 167 lb. per annum, which is equivalent to 7.5 cwt. of sulphate of ammonia. With increasing age of the stand this difference decreased due to the ingress of unsown white clover into the grass-alone plot. More accurate figures obtained from a current trial where there has been no ingress of white clover are shown below :

	Lucerne		*Timothy S.*51
	Du Puits	*Grimm*	
Nitrogen yield in lb. per acre 1953	310	294	16
,, ,, ,, ,, ,, ,, 1954	331	280	32

It is thus demonstrated that the legume has fixed at least 250–300 lb.

of nitrogen per annum, which is equivalent to over 11 cwt. of sulphate of ammonia per acre.

The residual effects of the mixtures were measured by growing a crop of rape on the experimental plots. The best results were obtained after lucerne alone, lucerne/ryegrass, lucerne/white clover and grass/clover mixtures, while the yields from the remaining cocksfoot-containing and red clover plots were much smaller.

A further lucerne experiment was laid down in 1952 in which the effect of strain, cutting frequency, companion grasses and nitrogen application were studied.

Over the whole three-year period Du Puits lucerne outyielded Grimm, both as pure sown plots and when sown with grasses. The latter strain gave yields similar to that of S.123 red clover.

Mean annual yields of dry matter in tons per acre

	Du Puits	*Grimm*	S.123 *red clover*
Sown alone	3.85	3.14	–
Sown with S.23 perennial ryegrass	3.95	3.34	3.01
,, ,, S.51 timothy	3.89	3.41	3.52
,, ,, S.215 meadow fescue	4.11	3.48	3.46
		±0.072	

It will be seen that in the case of Du Puits lucerne, sowing with ryegrass and timothy gives no advantage, while in the case of meadow fescue the superiority of the mixture is confined solely to the first harvest year. In fact after the second year, lucerne/grass plots were equivalent to pure-sown lucerne plots, as the sown grasses had been almost entirely eliminated. The grasses, however, made substantial contributions to the Grimm plots, particularly when nitrogen was applied.

The effect of an extra 2 cwt. of muriate of potash above the normal dressing of 2 cwt. has become increasingly apparent in the third year of the trial. Better survival of lucerne has been obtained, but only the Du Puits strain shows this characteristic. Figures for yields confirm this observation, as is shown hereunder :

Yields of dry matter in tons per acre of Du Puits lucerne

	Applications of muriate of potash cwt. per acre per annum	
	2	4
1953	4.60	4.60
1954	4.33	4.69
1955	2.61	3.13
Mean ± 0.072	3.85	4.14

The application of 7 cwt. of sulphate of ammonia per annum has given an overall increase of 38% dry matter, but this varied from 7% to 700% for pure sown lucerne and grass sown alone respectively. Du Puits sown without grass gave the smallest increase, but this was evident only in the first and third years. Grimm lucerne showed higher responses to added nitrogen when sown alone and with companion grasses. This is due to the fact that Grimm is far less competitive towards weeds, sown and unsown grasses, than Du Puits lucerne.

Over the first two years it was estimated that more than 76% of the sulphate of ammonia applied to the pure grass plots was recovered in the cut herbage. The percentage recovery varied with species as follows :

	Timothy S.51	*Meadow fescue* S.215	*Perennial ryegrass* S.23
Percentage nitrogen recovery	82.4	75.9	71.7

Twice cutting (nitrogen applied in two applications) gave a higher recovery than three times cutting (three applications).

After the last cut in 1956 the plots were ploughed and sown with rape to be followed by oats to measure residual fertility.

GENETICS AND INTERSPECIFIC HYBRIDIZATION

White Clover : Cyanogenetics. The distribution of genes concerned with the production of HCN in white clover has been described in a series of papers by Daday (1953a ; 1954a ; 1954b ; 1954c ; 1955). Two complementary independent genes are necessary for HCN production ; the enzyme linamarase (*Li*) hydrolyses the glucoside lotaustralin (*Ac*) into its components. The first paper described the frequency of these two alleles in European populations, and it was found that the frequency of the dominant alleles decreased gradually as the point of collection moved north and west from the Eastern Mediterranean region. This change was closely correlated with the January isotherms, and a decrease of 1°F. in the January mean temperature resulted in a reduction of 4.2% in the frequency of the dominant glucoside gene, and a reduction of 3.2% in the enzyme gene (Daday, 1954b).

This change in frequencies was confirmed in collections made on an altitudinal transect in the Alps, where similar changes in frequencies were observed. In addition, the intensity of the HCN

reaction, as measured by the picric acid test, was correlated with the dominant gene frequency (Daday, 1954c).

The frequency of these alleles in cultivated populations of white clover was also studied (Daday, 1954a; 1955). In a general way the frequency of the genes was correlated with the frequencies shown by samples of wild white clover in that area, but there was also evidence of the effect of selection of particular genotypes. The cultivated white clovers in this country had a high percentage of dominant alleles, while many of the European strains had a much smaller percentage, e.g., Ladino and White Dutch Clover had less than 10% of the dominant glucoside allele. It was possible to identify some of these strains on the basis of the results of these tests.

Further expansion of this study to world-wide dimensions was reported to the International Congress of Genetics in Italy (Daday, 1953a). The progressive change in the frequency of the alleles was similar to that observed in European populations, but certain factors tended to modify the pattern; in particular, white clover has only been introduced into some of these countries in comparatively recent times, so that natural selection has not had sufficient time to operate. In this respect the origin of the imported seed will have a marked effect on gene frequencies in the early years of establishment.

White clover : Leaf marks. In order to provide suitable markers for white clover strains the leaf-marking types, including anthocyanin marks, have been studied. The results confirm the work of Brewbaker[1] and others that leaf marking is conditioned by a series of alleles, the absence of marking being recessive. The marker alleles form a mosaic-dominance pattern, and the heterozygotes can be identified if the positions on the leaf are not identical. A similar independent allelic system has been suggested for the anthocyanin markings, but this has not yet been corroborated.

Lucerne genetics. Mr. M. M. Habib, Univ. of Alexandria, a post-graduate student working at the Station, is studying the inheritance of flower colour and other mutant characters in lucerne. It is hoped to use chromatographic methods to assist in the interpretation of the results.

Species relationships within the genus *Trifolium* have been investigated by Miss Alice Evans. The aim of this work was to investigate the possibilities of improvement by combining characteristics found in different species. *Trifolium* is a difficult genus in this respect, and techniques of grafting, emasculation and embryo culture were used in an attempt to produce hybrids. Grafting was

[1] Brewbaker, J. L. 1955. *J. Hered.* 46, 115-123.

first used to ascertain whether scion/stock crosses would be more successful than ungrafted controls. This was found not to be so, but it was useful as a preliminary sieve. Species that could be successfully grafted were more likely to produce hybrid embryos. In most cases hybrid embryos had to be excised at an early stage, otherwise they would abort. Hybrids were produced in *Trifolium repens* × *T. nigrescens*, *T. repens* × *T. uniflorum*, and *T. hybridum* × *T. ambiguum*. In the tribe *Trichostoma*, hybrid embryos were obtained in *T. pratense* × *T. medium*, *T. pratense* × *T. rubens*, and *T. pratense* × *T. alpestre*, but it proved impossible to grow these to maturity. Fertilization and initial embryo development were evident in some other species combinations, but attempts to culture these were negative. Embryological studies were made of the cause of embryo abortion, and it appeared in some cases that premature digestion of the endosperm by the vigorous hybrid embryo took place. This work is now being extended to the genus *Medicago*.

The morphology of the chromosome complexes has been under study to aid in the understanding of interspecific relationships in *Trifolium*. The length of the chromosomes in the species studied varied from 1 to 4μ and even within *T. repens* there was considerable variation, from the small chromosomes of *var. sylvestre* to those of intermediate size in *var. hollandicum*, while the largest chromosomes were found in *var. giganteum*.

Because of the small size of the chromosomes, constrictions were not easily observed. The two species *T. pratense* and *T. incarnatum* ($x = 7$), as well as *T. alexandrinum*, have one pair of chromosomes with satellites, and these were also observed in *T. repens*. *T. hybridum* has no satellites but has two pairs of small chromosomes as against the four pairs of *T. repens*. On the basis of chromosome morphology alone it was difficult to trace the mutual relationships of the species under study.

Pathology

Clover rot. The main object of the work carried out by A. J. H. Carr has been to select and breed a strain of red clover resistant to *Sclerotinia trifoliorum* and suitable for growing in those areas of Britain where the disease is prevalent. Since one-year leys are required for the four-course rotation practised, the later-flowering strains, although more resistant, are unsuitable and thus it has been necessary to select from material of the normally more susceptible early-flowering type. At the same time a programme of research has been undertaken to determine the extent of variation of the

pathogen, and whether such variation might adversely influence the breeding programme (Carr, 1954a ; 1954b).

A technique for the inoculation of three-weeks' old seedlings with mycelia in bran has been utilized for the initial selections (Carr and Davies, 1950). Survival rates were of the order of one in 1,500. Clones derived from resistant seedlings were tested again at maturity. Progeny tests were performed on F_1 families derived from a diallel cross of the most resistant material. Plants from F_1 families of six specially good parents were selected, and inter- and intra-family crosses made ; the second generation progeny has proved significantly more resistant than unselected controls. Seedlings from a third generation of selected plants have been established for field testing. Preliminary work on wild material from the centre of origin in the western European Mediterranean area has suggested that this line of approach is probably worth investigating more fully.

Work on the variation of the pathogen has been conducted on nine wild isolates, and 25 sets of eight spores from individual asci derived from these. The wild isolates differed markedly in pathogenic characters, and in growth rate on artificial media. Although certain isolates were from beans and sainfoin, as well as red clover, and were inoculated on to all three of these hosts, there was no evidence of physiologic specialization.

By the use of a marker termed "reaction", which is manifest as a white line produced when two mycelia of different genotype are co-inoculated on the same Petri dish, it has been possible to establish that three of the wild isolates were heterocaryons, and the remainder homocaryons, indicating a fairly high degree of outbreeding for a homothallic fungus. Heterocaryons arise by hyphal anastomosis between mycelia of different genotype, followed by nuclear migration through the thallus. Microconidia appear to be functionless. Heterocaryons were studied in relation to their constituent homocaryons, and examples of dominance and of positive and negative heterocaryotic vigour were noted both for growth rate and for pathogenicity to red clover. The single gene-controlled character of large or small ascospore, which could be determined *in situ* in the ascus, was used to demonstrate that a heterocaryon contained equal numbers of the two types of nuclei, and that nuclear pairing during the sexual stage was completely at random. New biotypes (reaction types) unlike either constituent homocaryon were recorded in the mono-ascospore progeny from heterocaryons.

The segregation of several characters was investigated. From co-inoculation of single ascospore lines within and between asci it

was concluded that at least three genes determine "reaction" type. The four genotypes from a single ascus frequently possessed divergent growth rates and differing pathogenic properties. There was an inverse correlation between these two characters. Ascospore size, the presence or absence of sclerotia and the time of formation and relative abundance of either microconidia or sclerotia were all controlled by a single gene.

Breeding a resistant although not immune variety of red clover, therefore, appears possible, although the pathogen is sufficiently variable to combat the efforts of the breeder. Heterocaryotic vigour of the fungus might in some cases lead to an attack of epidemic proportions, but only if heterocaryons remain stable throughout several seasons.

The year 1956 was particularly noteworthy for the high incidence of disease amongst herbage legumes in the field. Most of the common diseases were recorded as having caused more damage than usual. The fungus *Pseudoplea trifolii*, hitherto recorded only in white clover in Britain, caused severe defoliation on certain diallel crosses of lucerne involving one particular plant resulting from the cross Rhizoma × S.205. Practically all the plants in each family where this plant was used as a parent were infected (a note on this will be published in Plant Pathology). Crown wart (*Urophlyctis alfalfae*) was also observed in lucerne plots as well as the first record of *Verticillium* wilt (*Verticillium albo-atrum*). The most common disease of lucerne is leaf spot (*Pseudopeziza medicaginis*) followed by black stem (*Aschochyta imperfecta*), and some work on these two diseases is in progress.

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CEREAL, BEAN AND *BRASSICAE* BREEDING

By D. J. Griffiths

The oat crop is the most important and widely grown cereal in the Principality and ranks second only to grassland in importance as a source of food for livestock during the winter months. For this reason investigations dealing with oats, including the development of improved varieties, have been considered the prime function of the Station's Cereal Breeding programme.

Aims and results of earlier work

Work with oats was commenced as soon as the Station was founded and from the outset it was realized that the requirements in terms of varietal diversity would be greater than in the case of either wheat or barley on account of the wide range of edaphic and climatic conditions under which the crop is grown in Wales. Furthermore, the straw, as well as the grain, is of value for stock feed, so that in a breeding programme the quantity and quality of both have to be considered.

The actual plant breeding in its early stages followed two main lines, namely, the selection of pure lines from important Welsh " land " varieties, and the production of new varieties by hybridization.

The pure-line breeding method, which had been used so successfully by Swedish breeders just before the close of the 19th century in the development of Victory and Golden Rain from a Swedish " land " variety, was undertaken in the first place by Martin G. Jones, now of King's College, Newcastle-upon-Tyne, on the old " land " varieties Radnorshire Sprig, Ceirch-du-bach and *Avena strigosa* which had been grown in Wales for many generations and were well adapted to the poorer soils.

It was found in Radnorshire Sprig that little effective improvement could be accomplished through re-selection on account of the limited inherent variation within the variety, while Ceirch-du-bach and *Avena strigosa*, on the other hand, exhibited decided variation in respect of yielding ability, grain characteristics, length and strength of straw, heading, and date of maturity as well as disease resistance.

Although positive improvements were achieved by the pure-line method of breeding it soon became evident that better adapted varieties for the whole range of conditions under which oats are

grown could be obtained only through hybridization of selected parents.

As a result of the early agronomic researches commenced by Martin G. Jones and the detailed study and classification by the late C. V. B. Marquand of the chief varieties of oats in cultivation, the ecological concept of breeding for specific growing conditions was initiated and successfully developed by E. T. Jones, who remained in charge of this work until his appointment as Director of the Station in October 1950.

The breeding of new varieties through hybridization was developed to meet the needs of specific conditions for which purpose the work was divided into five sections, three in respect of spring varieties and two for winter varieties. This subdivision takes into account soil and climate, the specific adaptability to these conditions, and the general purposes for which the variety is grown. In respect of each the breeding aims are somewhat different, but certain objectives are common to all sections of the work.

In broad terms the general aims have been to increase yields of grain, improve the quality of both grain and straw, as well as the consistency of yielding ability from season to season.

The great limitation to the development of winter-hardy varieties of oats is that as a crop it has not the high expression of winter hardiness of either wheat or barley. Grey Winter is the most outstanding in this respect, consequently almost the whole of the winter oat breeding work has been based on this variety. Its chief defect, however, is its poor standing straw, and improvements were sought through hybridization with shorter and stiffer-strawed, white-grained varieties. From these crosses, varieties with approximately the same degree of winter hardiness as Grey Winter, but with greatly improved yielding ability and resistance to lodging were developed. Of the three varieties produced before the outbreak of World War II the best known are S.147 and S.172, the two most widely grown winter oat varieties today. These two varieties have gone a considerable way in fulfilling the winter oat requirements : S.147 for soils of medium productivity where good winter hardiness, white grain of good size and shape, straw of moderate length and good standing ability are the major needs, and S.172 for soils of very high fertility where a high grain-to-straw ratio, short straw with a high degree of resistance to lodging, satisfactory winter hardiness and good grain are necessary.

However, the experience of farmers who have grown these two varieties on an increasingly wide scale revealed the need for a variety

intermediate in straw length between these two, and possessing the better grain characteristics of S.147. Hybrids between these two varieties were produced in 1940 and from this date onwards the economic work on winter oats was centred on the development of this type of variety, at the same time intensifying the search for improved winter hardiness.

Several thousand segregate lines of the cross S.147 × S.172 were closely studied for the purpose of isolating selections possessing the most desirable attributes of both parents, namely, a combination of the slightly superior winter hardiness and better resistance to lodging of S.172 and the grain size, quality, and panicle characters of S.147. Owing to the apparent close association between short straw, short panicle branches and small grain size, selection for the desired character combinations proved difficult, with most of the progenies falling into the parental classes. By 1950, twelve selections had been finally isolated and seed increased for subsequent testing.

The cultivation of winter oats is mostly confined to the well-drained soils of reasonably good fertility, but spring oats are grown under a much wider range of soil and climatic conditions.

Until comparatively recent times cereal breeders have given most of their attention to the breeding of new spring varieties for the better soils and those of average productivity. The breeding of spring-sown varieties for the poorer soils, however, has received much attention at the Welsh Plant Breeding Station, and while progress has been slower and less spectacular than in the breeding of varieties for better soils, nevertheless steady advances have been made. In the first place, varieties adapted to these conditions, for example, Radnorshire Sprig, Englebrekt and *Avena strigosa* were used as parents for crossing with varieties possessing certain desirable features, and selections from these initial crosses later became available for further hybridization.

Two varieties have been developed by the Station through hybridization for soils of below-average productive capacity, namely, Ceirch Llwyd Cwta (S.171) released to farmers in 1936, was developed essentially as a fodder oat, and the black-grained variety S.220, released in 1945 as a reliable cropper on soils of only moderate fertility where it gives good yields of grain.

A substantial proportion of the oat acreage, in Wales especially, is grown on soils of medium cropping capacity and a particularly desirable feature of a variety intended for these conditions is a good range of adaptability on account of the wide difference in soil types that fall within this arbitrary category.

The first variety developed for these conditions was S.175, produced from a cross between Victory and the hardy Swedish oat Black Bell III, and was released in 1938. On account of its tendency to produce excessively long straw on soils rich in nitrogen this variety was withdrawn, and its place taken by Maldwyn (S.221), released in 1948. This latter variety, derived from the cross Victory × Radnorshire Sprig, has shown good adaptability for all soils of average productivity and where oats are required for feeding purposes it is specially recommended.

For the rich fertile soils where the major problem is an overabundance of straw and severe lodging, the main aims have been to develop early-maturing, short-strawed, low-tillering varieties with a high grain-to-straw ratio, grain of good size and of good milling quality and a high degree of resistance to lodging. The first spring variety developed by the Station for the richer soils was S.84, developed from a cross made in 1921 between the varieties Victory and Red Algerian and released in 1938. The chief aim in its breeding was to secure a resistance to lodging greater than that possessed by varieties then on the market. Further improvements in standing ability were achieved through hybridizing Victory and the short, stiff-strawed winter oat S.172 from which Milford (S.225) was developed. This variety, marketed in 1947, inherited in large measure the high degree of resistance to lodging of S.172, together with the spring habit of growth of Victory. Like its winter parent, it is a special-purpose oat for soils of high fertility, possessing short, strong straw.

Although main attention was given to the development of new varieties with superior grain, stiffness of straw and other morphological and physiological characters adapted to the various soil and climatic conditions, the importance of disease resistance was not overlooked.

The combination of resistance to crown rust (*Puccinia coronata avena*) and mildew (*Erysiphe graminis*) with desirable agronomic characters was the main feature of the Station's disease breeding programme for spring oats, and the combining of resistance to mildew and stem eelworm (*Ditylenchus dipsaci*) with desirable agronomic characters in winter oats.

Unfortunately, none of the varieties adapted to British conditions possessed resistance to either crown rust or mildew, consequently non-adapted forms of foreign origin, derived mainly from the red oat group (*A. byzantina*) had to be utilized as sources of resistance. The work with crown rust was complicated further by

the existence of a number of physiologic races each characterized by having different pathogenic capabilities.

The first cross between a crown rust resistant variety and an adapted variety was made in 1923, when Red Rustproof was hybridized with Scotch Potato, but because this variety only possessed resistance to a few of the existent physiological races, all the selections succumbed to attack. From 1947 onwards varieties possessing resistance to a far wider range of the forms in which the crown rust pathogen exists, such as Bond, Tama and Victoria, have been used as the chief sources of resistance in the breeding programme.

In breeding for resistance to mildew a series of selections exhibiting field resistance was first isolated from a cross between two selections derived from the hybrids Victory × Red Algerian, and Red Rustproof × Record, and one of these, namely, Selection 01747/10/7, was subsequently extensively utilized as a parent for further crossing with established spring and winter varieties.

In addition to the economic breeding work both agronomic and genetical studies were undertaken. When breeding experiments were commenced in 1919 steps were taken to determine the relative merits of indigenous old " land " and other varieties of oats under a range of environmental conditions. Out of these early studies, and those undertaken subsequently, one feature of basic importance emerged, namely, that from centre to centre according to the level of productivity, marked changes occurred in the ranking of varieties. As a result the breeders were then able to appreciate and assess the limitations of existing varieties, and to determine the combinations of varietal characteristics most likely to prove successful under the different levels of soil fertility.

Despite the fact that the development of new varieties for poor upland conditions showed substantial improvements in yield, agronomic investigations under these conditions showed that equally substantial improvements could be achieved in the overall production of oats by the use of balanced fertilizers and good quality seed.

In the course of the production of new and improved varieties the breeders were confronted with several important genetical problems, amongst which were natural crossing, occurrence of fatuoids and other aberrant grain types.

Opinions differed widely as to the sudden appearance of fatuoids or " false wild oats " in established varieties. From the exhaustive morphological and genetical studies of these types found in the

breeding material E. T. Jones proposed a modified mutation hypothesis of general application to fatuoids as well as sub-fatuoids and true-breeding awned types, in place of the alternative chromosome aberration hypothesis proposed by Huskins and Winge. In order to seek further evidence regarding the validity of the different hypotheses proposed, and the nature of the gene relationships involved, further studies of crosses involving species possessing wild and normal base-type articulations were also undertaken in the diploid, tetraploid and hexaploid groups.[1]

Prior to 1950 work with wheat and barley was carried out on a very limited scale. In winter wheat, investigations in the early years were restricted to the improvements by selection by T. J. Jenkin from within the old " land " variety Hên Gymro, formerly very popular in Wales for soils of below-average fertility because of its hardiness and ability to produce reasonably well-filled grain of good baking quality under adverse seasonal conditions. Two lines, namely S.70 and S.72, were selected for marketing as improved strains of this wheat. Work with spring wheat and spring barley was not commenced until 1946 when a limited number of crosses were made with the object of selecting forms adapted to the higher rainfall areas of the west.

OATS

The economic breeding work undertaken with oats during the six-year period 1950–6 may be regarded in all its essential features as a continuation of the programme outlined above. A large amount of hybrid material from different crosses made from 1940 onwards was studied and promising selections continued and tested in yield trials.

Winter oats

One of the immediate tasks undertaken with winter oats was the testing of an advanced group of S.172 × S.147 selections for the purpose of developing a new variety intermediate in length of straw between S.172 and S.147, and possessing grain approximating to that of the latter parent in size and quality. Eleven of these were included in the first series of trials conducted in 1950 but after four years of trial and gradual elimination, Selection No. 7 was earmarked for further seed increase. In 1956 Selection No. 7 successfully completed its 3-year period in the official series of primary trials with the

[1] Jones, E. T. 1941. *Genetica* 22. 419-434.

N.I.A.B., Cambridge, and as a result was recommended for release as a new white winter oat variety carrying the name Powys (S.226), a brief description of which appears on p. 166. This new variety partly fulfils the need for a third winter oat variety intermediate between the ultra-short-strawed high fertility-demanding S.172 and the longer strawed high-yielding general-purpose oat S.147.

Two new selections derived from a cross between S.147 and the unnamed selection 0379, showed further substantial improvements in yielding ability over all other established varieties in trials conducted during seasons 1951–1956. These two selections have proved equal to S.147 in hardiness and lodging resistance whilst at the same time possessing a better grain-to-straw ratio and better grain yield. Selection V.907 matures fairly early and has grain of good quality ; V.1022 is somewhat later ripening and the grain is of a slightly inferior quality.

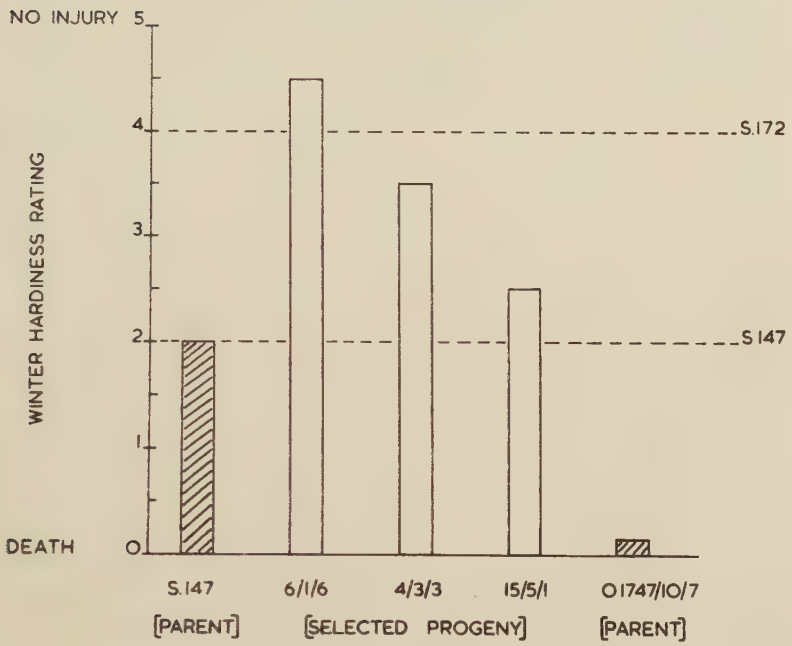
A series of short, stiff-strawed selections developed from the cross S.147 × Milford was tested for yielding ability and observed critically for their growth behaviour. Although superior in several respects, with few exceptions these proved decidedly inferior to the S.172 × S.147 selections in winter hardiness. This important difference in the two groups of selections was clearly borne out in the 1953/4 and 1955/6 seasons. In the 1953/4 season the selections derived from the former cross were completely winter-killed whilst the S.172 × S.147 derivatives survived to give full stands in the plots.

Amongst the hybrid progenies of crosses involving S.147 and certain spring parents a small proportion of lines showed decided superiority in hardiness even over their winter parent during the two severe winter seasons ; the most winter-hardy types proved to be a number of mildew-resistant selections derived in the first place through crossing S.147 with the spring type mildew-resistant selection 01747/10/7. In other crossing combinations of winter × spring types, however, no improvement in hardiness over the winter parent was noted in any of the segregates.

The relative hardiness ratings (based on an arbitary 0–5 scale with 5 representing very slight or no frost injury) for the most promising selections derived from the two crosses S.147 × 01747/10/7 (Fig. 1), and S.147 × S.225 (Fig. 2), are presented in relation to their respective parents.

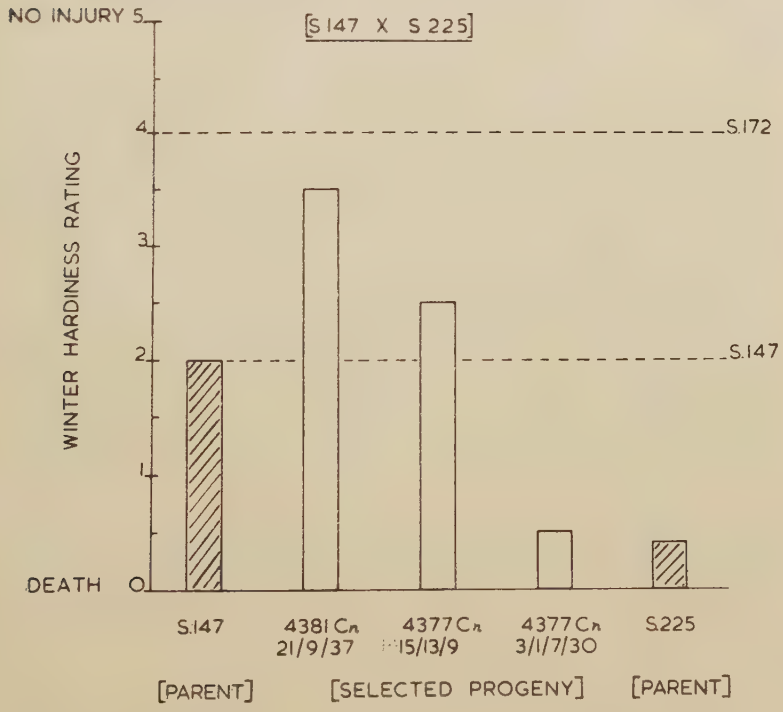
WINTER HARDINESS IN OAT CROSSES 1955-56.

4744 Cn (S.147 X O 1747/10/7)



WINTER HARDINESS IN OAT CROSSES 1955-56.

[S 147 X S 225]



The heavy winter-killing which resulted from the unusually hard frosts experienced in January and February of 1954 and 1955, provided excellent opportunities to effect positive selection for winter hardiness and to assess the behaviour of established varieties under such conditions. Of the established varieties Grey Winter showed least evidence of frost injury, while both S.172 and Powys (S.226) showed a slight but significant superiority over S.147.

In view of the increasing importance of stem eelworm as a pest of winter oats it was decided in 1950 to embark on a series of experiments to enquire more fully into the potential value of resistant varieties on infested land and to develop suitable field techniques for detecting resistant lines in hybrid material. For this purpose two acres of land known to be heavily infested with the nematode were taken over for a period of three seasons in the course of which it was possible to test the reaction of all the winter hybrid progenies of crosses involving resistant and susceptible parents.

At the outset of these investigations it was known from the work of the late Dr. T. Goodey of Rothamsted, that Grey Winter, S.81, and Picton possessed resistance and that S.147 was susceptible, consequently screening tests during the first season were confined to the progenies of crosses involving these resistant varieties and susceptible forms, chiefly S.147. However, in the same year evidence of resistance in the two Station-bred varieties S.172 and Milford (S.225) was obtained and subsequent selection work was therefore extended to hybrid progenies involving these varieties.

In all, upwards of 5,000 winter segregates from 14 different crosses were tested for eelworm reaction at this centre and the seed of those possessing resistance combined with desirable agronomic characters was increased. Twenty-two of the most promising stem eelworm resistant selections were chosen for inclusion in the 1955–56 rod-row yield trials.

The combination of mildew resistance with winter hardiness was successfully accomplished during this period and progress was made in isolating high-yielding, winter-hardy, mildew-resistant lines possessing grain of good quality and of satisfactory colour. The most promising of these were selected as parents for crossing with various stem eelworm-resistant types with the aim of combining the two types of resistance into a single variety.

Spring oats

Breeding work with spring oats for the different levels of fertility was continued throughout the period 1950–56, but in the

main primary attention was given to the production of high yielding varieties for the average and above-average fertility conditions. The programme of work for upland conditions was concerned mainly with testing at a hill centre a series of selections developed from crosses made between Englebrekt and 464/24/2 (Radnorshire Sprig × Victory), and an earlier maturing S.220 type from the progenies derived from that variety crossed with Maldwyn (S.221). One selection from the former cross proved higher yielding than S.220 in small scale trials and because of its early maturity, Selection D2973 was included for further tests in the national series of upland oat variety trials. Several of the black-grained selections from the S.221 × S.220 backcross hybrid material also showed promise in respect of their suitability for upland conditions and one of these, possessing slightly shorter and finer straw than S.220 and maturing several days earlier was seed increased in 1956 for further trials at several centres.

Since the release of Milford (S.225) in 1948 the chief interest in soils of high productivity was centred around Selection D1670 developed from the cross S.84 × Eagle. It possesses short plump grain, has straw which is slightly shorter and stiffer than Sun II, ripening about 2–4 days later and comparing favourably with it in grain yields in all trials conducted at the Station and at other trial centres located in the west and north of the country.

Breeding for disease resistance

Progress has been made in the development of desirable agronomic types possessing resistance to both crown rust and mildew from the cross 01750/11 × Tama and stiff-strawed mildew-resistant selections from crosses between Milford (S.225) and 01747/10/7. The value of mildew resistance is well demonstrated by the results obtained from yield trials carried out in 1954 when a heavy attack of mildew developed early in the season. The results presented below for seasons 1953 and 1954 clearly indicate the superiority of the resistant selections over both S.84 and Sun II under conditions of high incidence of the disease.

Variety or selection	*Parentage*	*Reaction to mildew*	*Relative yields* 1953 *Mildew Slight*	1954 *attack Heavy*
Sun II	Eagle × Star	Susceptible	100.0	100.0
S.84	Victory × Red Algerian	,,	103.1	85.6
4757/6/2/19	01750/11 × Tama	Resistant	108.5	139.6
4757/18/2/19	01750/11 × Tama	,,	111.6	134.0

The increased difference in grain yield between the resistant and susceptible groups of varieties in 1954 was due entirely to a reduction in yield of the susceptible varieties resulting from attack by mildew. This fact was further borne out by the results obtained from the other six mildew-resistant selections included in the 1954 trial. With one exception all of these also gave grain yields ranging from 25 to 68% higher than the control varieties and other susceptible selections.

In addition to 01747/10/7 and 01750/11, an unidentified hexaploid (Cc 4146) believed to be a natural hybrid derived from *Avena sativa* × *A. ludoviciana* has been used as another source of resistance, but on account of the several undesirable features possessed by its grain progress has been slow. Resistant white-grained selections made from the F_4 generation of crosses between this form and Sun II have been used recently for further crossing and back-crossing.

It is encouraging to report that over a period of years no new pathogenic forms of mildew capable of attacking the types of resistance utilized in the breeding programme have appeared in the field although subjected to continuous infection both at Aberystwyth and at various centres in South-West England.

Crown rust, on the other hand, has exhibited considerable pathogenic variability, and in consequence progress in the development of resistant selections has been retarded. Up to 1952 derivatives of crosses possessing the resistance factors of Bond, Tama and Victoria had proved resistant to all races then known, but in July of that year these selections succumbed to attack just before maturity. Collections of uredospores made from the field nursery revealed the existence of two new races (later designated as Races 274 and 275) which had not been identified previously. Greenhouse tests showed that derivatives possessing the Bond type of resistance were susceptible to both races, whilst those derived from Tama and Victoria proved moderately susceptible to Race 274 but resistant to Race 275. Race 275 reappeared in the field nursery in 1953 and 1954 but only slight traces of Race 274 have been observed on the Tama and Victoria derivatives. In greenhouse studies conducted in 1952 and 1953 two new varieties, namely, Landhafer and Santa Fé, were found to be resistant to all 13 races identified to date. Landhafer was used for the first time in crosses as a source of resistance to crown rust in 1952.

With the identification of resistance to stem eelworm in Milford (S.225) certain hybrid progenies of crosses between this variety and others were screened for resistance during 1953 and 1954, and in

addition a programme of back-crossing was initiated in 1956 with a view to incorporating resistance into established spring varieties. A search for other sources of resistance from amongst the spring varieties also was undertaken. In tests involving upwards of 200 spring varieties of British and foreign origin, only Victoria and some unnamed *Avena byzantina* forms from Turkey showed no symptoms of attack. Clearly, since no resistance has been found in any other adapted spring varieties the development of improved stem eelworm resistant types must be based largely on the variety Milford (S.225).

Data on the mode of inheritance of resistance to this nematode were obtained during 1955 and 1956 for the F_1 and F_2 families of various crosses and these together with the previous data collected on F_3 and F_4 progenies suggest that resistance of the Grey Winter type is primarily controlled by a single dominant genetic factor, (Jones, J. M . *et al.* 1955).

Of the three leading cereals grown in this country, the oat crop is the most severely affected by the cereal root eelworm (*Heterodera major*) and because of recent reports indicating increased incidence of the pest it was decided to investigate whether certain varieties succumb less readily to attack than others. For this work, an area of land in Flintshire known to be infested with cereal root eelworm was taken over for observing the reactions of various varieties and forms of oats grown under such conditions, and in 1955, 1,406 different lots of oats derived from the World Collection in the United States Department of Agriculture were sown, together with 42 miscellaneous varieties and types derived from other sources. A heavy and fairly uniform attack by the root eelworm was experienced and it was possible to observe certain differences in varietal reaction.

Reaction to infection in the first place was based entirely on the ability or failure of the material to make normal growth, lots giving pale green, poorly developed plants were classed as susceptible and discarded whilst those which made vigorous growth were earmarked for a re-test in 1956. Out of the total 1,448 lots tested only 195 made reasonably satisfactory growth and these were classified as follows :

Species	*No. of lots*	*General remarks*
Avena abyssinica	3	General productivity extremely low
A. byzantina	108	Extremely early maturing types with inferior grain
A. nuda	3	—
A. sativa	81	Some promising lots with fairly good quality grain

Through the co-operation of the Provincial Advisory Entomologists of the N.A.A.S.(Wales), (Bangor Sub-centre), it was possible to undertake cyst counts on a number of the apparently resistant types, but apart from the *Avena abyssinica* forms which are wholly unadapted to British conditions, none were found entirely free of eelworm cysts on their root systems. In the 1956 yield tests undertaken at the same centres none of the better adapted *Avena sativa* types earmarked as possible resisters in 1955 showed any clear-cut superiority in cropping capacity over Sun II, and again it was only the tetraploid *A. abyssinica* types which possessed cyst-free root systems.

Agronomic investigations

Grazing Trials

The first of a series of agronomic trials was undertaken by J. D. Hayes in 1955/56 to determine the effect of spring grazing on the subsequent grain yield of winter oats. A factorial experiment was laid down involving defoliation and various applications of nitrochalk during February, March and April. In a crop of S.172 yields of between 250 and 375 lb. of dry matter per acre were obtained during the spring, with crude protein content fluctuating between 21% and 29%, depending on the fertilizer treatment and date of cutting. No significant differences in grain yield were detected after the various defoliation and manurial treatments. Further work, however, is to be conducted over several seasons before any conclusions can be drawn from these investigations.

Mixtures of varieties versus *pure stands.* During the last four years, a series of trials has been carried out to determine the effects of competition on varieties when grown as mixtures over several seasons, and to determine whether or not there is any advantage in growing oat varieties as a mixture over growing them as pure stands. In all the tests the mixtures of two varieties equalled or produced more than the higher yielding component variety grown separately. A consistent "shift" occurred from year to year in the proportions of the varieties, but the higher yielding component when grown singly did not always become the dominant variety in the mixture. Over a period of five seasons there was a gradual domination of the higher tillering component type in each of the twelve mixtures studied. The fact that the one yielding best alone will not always be that which survives under competition, is of significance in relation to the likelihood of recovering superior yielding lines from hybrid

progenies which have been continued without selection on a population basis for several generations.

The influence of sward composition and sward management on the following oat crop. After a grass strain trial conducted over a five-year period it was decided to observe the effects of treatments imposed on the yield and character of an oat crop grown on the experimental area. The grass strain trial was originally designed to compare the agronomic behaviour of S.24 and Irish perennial ryegrasses in three types of seeds mixtures subjected to two systems of management and to two levels of fertilizer applications. Despite marked differences in botanical composition in the last year of the plots before ploughing (1952), the yields of oat grain following S.24 and Irish perennial ryegrasses subjected to the same management and fertilizer treatment were remarkably similar, but both yield of grain and straw had been influenced greatly by sward management. All the grazed sub-plots, both unmanured and manured, gave superior yields to the corresponding series of sub-plots which were managed for hay. Furthermore, the data indicated a greater difference in yield between the grazing and hay treatments on the manured than on the unmanured plots.

CYTOGENETIC STUDIES

Occurrence of unstable types in hybrid lines of hexaploid oats. In the course of breeding for resistance to crown rust, sterile dwarf plants appeared among the progenies of certain selections of a cross between the two hexaploid species *Avena sativa* × *A. byzantina.* Apparently normal and fully fertile segregates from the F_6 generation which were continued as promising disease-resistant lines, on further selfing of the phenotypically normal plants continued to yield the same proportion of sterile dwarfs in successive generations. During four generations of inbreeding, progenies of some 44 unstable normals involving 2,136 individual plants were examined and amongst these only 232 phenotypic normals appeared. No true-breeding fully-fertile lines were recovered from the progenies.

Cytological examination of this material carried out by Professor P. T. Thomas, Dep. Agric. Bot., U.C.W., Aberystwyth, revealed several features of interest. The dwarf sterile progenies were found to be of the 40-chromosome type, while the unstable normal plants possessed the full complement of 42 chromosomes.

Meiosis of the unstable plants was unexpectedly regular, only rarely was failure of chromosome pairing observed and it was estimated that less than 10 per cent of the young pollen grains

contained deficient chromosome complements. Observation at pollen grain mitosis also revealed no further loss than had already occurred at meiosis.

In an effort to discover the precise stage at which chromosomes were eliminated to give nullisomic plants, developing embryos were examined. Early embryonic development appeared normal, but at the stage of reduced mitotic activity, which occurs before dormancy, the extrusion of chromosomes from the nucleus could be observed. The precise mechanism of this elimination is not yet clear, but it is evidently associated with a critical phase in the process of mitosis.

From the breeding behaviour of the unstable plants through several generations of selfing, and when crossed with stable lines, it is apparent, however, that this abnormality is subject to genetic control.

Species relationships and artifical polyploidy in the genus Avena. This work was started in 1951 by D. J. Griffiths and J. H. W. Holden, but on the resignation of Holden to take up an appointment at King's College, Newcastle-upon-Tyne, it was later continued by D. J. Griffiths, D. G. Rowlands and W. T. H. Peregrine.

The wild diploid and tetraploid *Avena* spp. represent a possible source of further genetic variation for use in the programme of breeding for improved varieties of oats. During 1951 an investigation was begun which had as its ultimate aim, the synthesis of new hexaploid forms for crossing with cultivated varieties in order that desirable characters of the former might be transferred to *A. sativa.*

It was assumed that the evolutionary origin of the cultivated hexaploid oats was in general terms similar to that of the hexaploid wheats, that is, from a natural doubling of the chromosome complement of a triploid form derived from a cross between a tetraploid and diploid species. The process can be repeated experimentally by the artifical hybridization of tetraploid and diploid species, the derived triploid as a young plant being subsequently treated with aqueous colchicine solution to produce hexaploid progeny.

Initially, crosses were made between diploid × diploid and tetraploid × tetraploid species to gain information from the hybrids on the genome relationships of the wild species. Data from analysis of some of the diploid × diploid crosses are summarized as follows :

Hybrid	*Per cent. seed set*	*Chromosome pairing*
S.75 × *A. nudibrevis*	80.0	7 bivalents
S.75 × *A. wiestii*	57.3	,,
A. nudibrevis × *A. wiestii*	54.1	,,
A. strigosa ssp. *hirtula* × *A. strigosa* ssp. *glabrota*	73.2	,,
A. strigosa ssp. *hirtula* × *A. longiglumis*	0.2	Associations of 3 to 8 chromosomes present
S.75 × *A. longiglumis*	0.1	,,
A. brevis × *A. longiglumis*	0.0	,,

It will be noted from the above that apart from the crosses involving *Avena longiglumis* which are being investigated in collaboration with Prof. P. T. Thomas, all the hybrids obtained were fully fertile but those between *A. longiglumis* and the other species gave a fertility of less than 1.0 per cent. The occurrence of multivalents in those hybrids involving *A. longiglumis* must be regarded as being responsible for their high degree of sterility. Tetraploid progeny derived from the *A. strigosa* subsp. *hirtula* × *A. longiglumis* cross through colchicine treatment showed a fertility which although somewhat variable approached about 50 per cent.

Crosses between the tetraploid species of *A. abyssinica, A. barbata* and *A. vaviloviana* were investigated both cytologically and genetically and a structural interchange was noted during meiosis in all the hybrids, but it is not yet clear whether the chromosomes involved are the same in all the crosses.

The cross between autotetraploid S.171 × *A. abyssinica* was studied in detail. The fertility of the F_1 hybrid was well below 10%, and equally disappointing seed sets were recorded for the F_2 generation. Out of a total of 39 F_2 plants examined, 22 proved to be completely sterile, and in the remainder the highest seed set was only 7.5 per cent. All the F_3 generation progenies studied gave extremely low seed sets and in consequence offer little scope for the development of satisfactory tetraploid forms of *Avena* for British conditions.

Simultaneously with the study of the relationships of the diploid and tetraploid species, triploid hybrids have been produced which after colchicine treatment have yielded hexaploid progeny. Such synthetic hexaploids have been obtained from the following crosses :

A. barbata × *A. hirtula*
A. barbata × *A. longiglumis*
A. abyssinica × *A. brevis*

A study of meiosis in the triploid F_1 revealed a close affinity between the *hirtula* genome and one of those from *barbata*. This is reflected in the formation of multivalents in the synthetic hexaploid and also in its incomplete fertility.

Attempts to hybridize this synthetic hexaploid with natural hexaploid species showed interesting results. In 1953 all crosses were made using the natural species as female parents only, and no hybrids were obtained. In 1954, however, when the natural species were used as pollen parents, a number of hybrid seeds developed, and in the case of synthetic 6x × *A. sterilis* as many as 50% of the pollinations produced filled grain. Details of these crosses are given in the table below.

	1953		1954	
	Number of		*Number of*	
Cross	*Pollinations*	*Grains*	*Pollinations*	*Grains*
A. sativa × synthethic 6x	131	0	–	–
Reciprocal	–	–	189	32
A. byzantina × synthetic 6x	127	0	–	–
Reciprocal	–	–	19	0
A. fatua × synthetic 6x	110	0	–	–
Reciprocal	–	–	32	1
A. nuda × synthetic 6x	110	0	–	–
Reciprocal	–	–	57	8
A. sterilis × synthetic 6x	93	0	–	–
Reciprocal	–	–	88	44
A. ludoviciana × synthetic 6x	–	–	–	–
Reciprocal	–	–	40	2
Cc4146 × synthetic 6x	77	0	–	–
Reciprocal	–	–	–	–

A detailed cytological analysis of three of these crosses indicated poor pairing between the chromosomes with the number of univalents at meiosis ranging from 3 to 21.

Chromosome pairing was essentially similar in all crosses thus providing further evidence of the close affinity between the various natural hexaploid species. Bivalent formation in the hybrids proved

very much lower than in the amphidiploid parent, the mean value for the former being 7.8 with a range of 1–13, compared with 14.34 with a range of 8–21 in the parent.

All the hybrids so far examined have proved to be completely sterile, but although high numbers of univalents are present in most cells it is doubtful if lack of pairing is the complete explanation of this sterility.

Further crosses involving additional synthetic hexaploids have been obtained and are now undergoing investigation. From preliminary results so far available the same general picture is obtained suggesting that all the synthetic hexaploids studied behave very similarly in crosses with natural hexaploid species.

Induction of mutations in oats through seed irradiation

Irradiated seed of both S.147 and S.172 was grown in the nursery as spaced plants in 1955 and again sown in the autumn of the same year as separate populations for general observation under field conditions. Apart from the large numbers of albino seedlings which appeared in several lines after sowing no obvious morphological variants were observed in the X_2 generation of either variety. At harvest, representative panicles were taken from all the populations for purposes of continuing the search for agronomically useful mutants in the coming season.

In an experiment designed to study the effects of irradiation on mutation-rates in wild species of oats, two lots of seed of *A. sterilis maxima* containing 10 per cent. moisture were exposed to X-ray dosages of 20,000 and 30,000 . units respectively in 1954. The X_1 generation plants produced from the treated seed were harvested separately, and in 1955 forty plants were grown from each for detailed observations of grain characteristics on a single plant basis in the X_2 generation.

Examination of these plants revealed the presence of a number of mutations in both the 20,000 and 30,000*r* treated groups, whereas non-irradiated seed from the same original stock and grown under the same conditions gave no aberrant forms. The two predominant mutations were changes in grain colour and mode of floret disjunction.

Out of a total of 227 lines of irradiated material examined, the aberrant type of floret disjunction was observed in 12 lines, in each of which from one to seven such plants occurred. Although the mutant plants were not observed in detail in the field, it was noted in some cases that they were somewhat lacking in vigour and were

erect instead of haivng the characteristic ascending habit of *A. sterilis maxima*. The panicles were smaller with less than ten spikelets, and the overall dimensions of the spikelet parts were 70–80% of the normal.

The most important characteristic feature of the mutants was in the morphology of the spikelets themselves. Instead of the usual number there were up to nine florets, in some cases as many as the first six having well-filled grain, and all bearing a geniculate awn on the outer palea except the uppermost one or two, which bore only a small straight awn. Each floret was articulated with its neighbour by means of a well-developed and readily separated sucker and callus pad exactly similar to that found at the base of the first floret in the wild stock. Hairiness also was markedly different in these mutants, a tuft of hairs being present on the base of every floret and on each rachilla segment.

The lines producing these fatuoids could be divided into two groups, namely, those in which the mutants were completely sterile and those in which the fertility was as high as in normal *A. sterilis maxima*. Fatuoids of intermediate fertility were not found and there were no sterile and fertile forms present in the same line. Differences between the two groups were slight except for a further reduction in vigour and slightly earlier panicle exsertion in the sterile fatuoids.

Apart from the rather high number of florets formed on each spikelet, these fertile fatuoids closely resembled the true *Avena fatua*, and it is suggested that this latter species could well have arisen through a mutation of this type from *Avena sterilis*, as indicated by Coffman. This theory is not in conflict with the evidence from phytogeography, since most authors agree that Asia Minor is the centre of origin of oats, and both Vavilov and Malzew state that *A. fatua* and *A. sterilis* are found growing together in that region.

Study of Variation in Panicle and Culm Characters in relation to Population Density in Oats (E.T.J. and I.T.J.)

Seeds of the following four varieties were sown in small plots at three seed rates, low, medium and high : Maldwyn (S.221), a small-grained, high-tillering variety ; Marvellous, large grained and low–tillering ; Milford (S.225) and Victory, representing intermediate types. The experiment was started in 1954, and repeated in 1955. The weather conditions in 1954 were dry during April, May and June, and wet during July and August ; in 1955 they were

the exact reverse. Yields were higher in the latter year. In both years there were significant differences between variety yields, but the ranking of varieties varied with season, Marvellous and Victory being more adversely affected by the early dry conditions of 1954 than the two other varieties.

Variety	*Yield of grain in gms. per 10 ft. of drill (drills 12" apart)*	
	1954	1955
Maldwyn (S.221)	290.2	336.5
Milford (S.225)	229.0	353.2
Victory	193.8	389.2
Marvellous	207.8	414.7
Seed rate		
Low = 69 lb. per acre	228.4	357.0
Medium = 137 ,,	237.6	384.5
High = 206 ,,	224.5	378.7

L.S.D. (P = 0.05) between varieties = 29.8 (1954) ; 20.8 (1955)
,, ,, ,, seed rates = 25.8 (1954) ; 18.0 (1955)

Analysis of plant samples of the 1954 harvest indicates that within the varieties Maldwyn (S.221) and Marvellous there was a tendency towards equalisation in panicle numbers as between the low and high seed rates. This was brought about in Maldwyn (S.221) by higher tillering at the low seed rate, and in Marvellous by rather heavy mortality of tillers or plants at the high seed rate. Large differences, however, occurred in panicle numbers between low and high seed rates in Milford (S.225) and Victory. Marvellous gave the lowest number of panicles and heaviest weight of grain per panicle in all three treatments, and Maldwyn (S.221) the reverse.

The number of spikelets per panicle was significantly reduced by the high, compared with the low, seed rate. Reduction in number of spikelets per panicle was related to the number of spikelet-bearing whorls per panicle and more especially to the presence or absence of whorls 4, 5 and 6 (counting from panicle apex downwards) and the numbers of spikelets on the latter. In the variety Marvellous under the more intense inter-plant competition of the high rate of seeding there was a reduction of 80% in the number of panicles bearing six whorls. In all varieties the greatest fluctuation in spikelet numbers occurred in the whorls situated towards the

base of the panicle, there being little variation in the sum total of spikelets borne by the uppermost whorls (1–3). Under the low seed rate whorl 5 exceeded whorl 4 in weight of grain, but at the high rate of seeding the largest weight of grain was borne by whorl 4. In Milford (S.225) and Marvellous at both low and high seed rates whorl 5 gave the highest correlation with total weight of grain per panicle.

In general the high rate of seeding, compared with the low, produced shorter culms and lighter panicles, and a tendency to earlier lodging and earlier ripening. The decrease in panicle weight was mainly a reflection of a reduced number of whorls per panicle and the associated changes in the number of spikelets at the lowermost whorls.

BARLEY AND WHEAT BREEDING

Breeding work on spring barley and spring wheat has been carried out on a very limited scale. In Wales, barley is grown almost entirely for livestock feed and the most widely grown variety in the coastal area is the old "land" variety, Hên Gymro, which ripens fairly early and is highly resistant to grain shattering when ripe, but possesses very weak straw. No marked improvements in standing ability were achieved through pure-line selection, consequently crosses were made between Hên Gymro and the newer stiff-strawed feeding barleys with the object of developing a stiffer-strawed, early-maturing, non-shattering type of feeding barley suitable for the coastal areas. Some of the most promising selections were provisionally seed increased in 1954 for yield tests. In 1955, 13 selections derived from the crosses Camton × Hên Gymro, Plumage Archer × Hên Gymro, and Balder × Hên Gymro were included in a small plot yield trial with Herta as control. Three of these proved equal to the control in yielding ability, namely, selections 23Co 3/5/22, 23Co 2/22 (both derivatives of the cross Plumage Archer × Hên Gymro) and 29Co 5/28 (Balder × Hên Gymro). Although none of these showed any real improvement over Herta in respect of yielding ability they were a decided improvement over the Hên Gymro parent in this respect as well as in stiffness of straw and date of maturity.

A series of 6- and 2-rowed isogenic lines of barley was kindly supplied to us by Dr. G. A. Wiebe, U.S. Department of Agriculture, Beltsville, Washington, D.C., in 1954. These were grown in a split-plot design layout during 1955 and 1956, with the object of assessing whether the 6-rowed forms in this country would show

superiority in grain yield capacity over the 2-rowed lines, as they had done in United States. Analysis of the results obtained from ten pairs of lines tested revealed a significant superiority of the 6-rowed types over the 2-rowed lines. Six pairs of these lines have been selected by J. D. Hayes for detailed genetic analysis for which a diallel cross has been performed giving 144 crosses with ten F_1 seeds per cross. The F_1 and F_2 will be sown as spaced plants in the field during 1957 for the purpose of assessing the value of the diallel technique in commercial barley breeding.

Work with spring wheat has been confined to the development and subsequent testing of segregates from the crosses Jubilégem × Red Fife, Holdfast × Rival, Bersee × Rival and Jubilégem × Rival. These were designed to produce a variety suitable for spring sowing under Welsh conditions. Of these, five selections have shown some promise in respect of earliness of maturity, yielding ability and standing qualities. One such selection from the cross Jubilégem × Red Fife has been particularly outstanding and, together with the other promising selections, has been re-selected and multiplied for final testing.

FIELD BEANS

During the last half century there has been a steady decline in the national acreage of beans. At the same time a slight fall in the average yield per acre has occurred which is in striking contrast to the marked improvements achieved in the yielding ability of other grain crops.

Breeding work with the crop was first begun in 1944 to effect improvements in the date of maturity and seed-setting capacity of spring beans. Subsequently attention has been directed towards winter beans.

Efforts to develop improved types by pure-line selections met with discouraging results. Individual plant selections made in the field from various populations revealed loss of vigour upon selfing, and in no instance did single plant selections show superiority in yielding ability over the stock from which they were derived when tested over a number of seasons. It was found that considerable natural crossing occurred in adjacent drills thus making the maintenance of small plots and assessment of progenies an extremely difficult and complicated task.

Investigations of the extent of natural crossing were carried out using a distinctive homozygous recessive flower colour line as the tester strain. Seed harvested from the tester plants was sown

in the following season and all hybrids amongst the progenies could be quickly recognized. Using a series of different experimental layouts the results obtained showed that intercrossing between lines grown in contiguous drills ranged from 30–40%, but progressively decreased with increasing distance from the contaminant and also with increases in plot size.

The proportion of natural crossing occurring suggests that the breeding system is perhaps adapted to considerable cross-pollination and an experiment was designed to observe the effects of insect visitation on pod- and seed-setting. Increases were observed in number of pods per plant as well as number of fully developed seeds per pod in all plants grown in cages into which bumble bees had been introduced. A summary of the results obtained is given below :—

Selection	*No bees*		*Bees introduced*	
	Mean number of		*Mean number of*	
	Pods set	*Seeds per pod*	*Pods set*	*Seeds per pod*
Ch 87/4	6.75	1.96	8.05	2.40
Ch 93/3	3.25	2.40	8.25	2.85
Ch 170 (white flowered)	6.75	1.81	12.50	2.68
Ch 141	6.50	2.30	8.75	2.63
General means	5.82	2.08	9.50	2.66

Pods harvested from the Ch 170 plants in cages into which bees were introduced were classified into two groups : (a) pods containing less than 3 seeds, and (b) those with 3 or more seeds. The seed derived from each group was sown in the following season and the proportion noted in each group which had developed as a result of selfing and cross-pollination respectively. The results obtained were as follows :—

	No. selfed (*White flowers*)	*No. of hybrids* (*Coloured flowers*)	*Percentage outcrossing*
Ch 170 (a)	15	5	25
Ch 170 (b)	27	24	47

It is thus apparent that the general improvement in seed setting in the pods was almost entirely attributable to the foreign pollen introduced by the visiting bees. Furthermore, the hybrid plants which appeared in the two populations proved to be decidedly more vigorous, and, as shown below, produced higher pod numbers and a better seed set per pod than the inbred plants :—

Selfed plants = 17.6 pods with a mean set of 2.7 seeds per pod
Hybrid plants = 27.6 pods with a mean set of 3.1 seeds per pod

These data, together with information obtained by D. G. Rowlands from a cytogenetical investigation of the breeding system, suggest that beans are inherently suited to a fairly high degree of hybridity for which due allowance must be made during improvement work.

Further evidence of hybrid vigour and improved pod-setting resulting from outcrossing has been obtained by using the white flowered lines Ch 170 and Cp 145, the latter being similar to Ch 170 except for the presence of the melanic spot on the wing petals. These lines allow all hybrids formed as a result of outcrossing to be readily recognized at a very early stage in development thus rendering possible a direct comparision of pod-setting in inbreds and hybrids.

Mean values for pod- and seed-setting in inbred and outcrossed lines of field beans

	Ch 170		*Cp* 145		*Random plants from a population of tick beans*
	Inbred	*Hybrid*	*Inbred*	*Hybrid*	
Pods per plant	3.04	4.49	4.52	6.21	8.06
Seeds per plant	6.42	11.02	13.90	17.70	19.63
Seeds per pod	2.11	2.45	3.08	2.85	2.44

Although pod values were low in all instances it can be seen that the hybrid material derived from both lines produced more pods per plant than the inbred plants, and in Ch 170 there appears to be evidence of improved seed setting within individual pods associated with the hybrid condition. The comparable results given for a group of plants taken at random from a stock of tick beans underlines the rather high degree of hybridity that exists in populations constituting commercial varieties.

In spite of the undoubted theoretical possibilities of the hybrid vigour approach to bean breeding, the practical difficulties involved with such a project have necessitated an investigation of the possibilities of self-fertile lines. A long-term analysis of the effects of inbreeding in field beans has been initiated by Rowlands and the possibility of isolating vigorous self-fertile, self-tripping lines from existing populations has been envisaged. Results so far obtained

from the study of over 300 selfed plants indicate that differences in self-compatibility do exist between plants, but the problem of self-tripping has still to be overcome.

In the field, the work of selecting for type in winter and spring beans is continuing on a population basis. Several of the winter bean stocks have exhibited outstanding winter hardiness, only slight winter-killing being observed even during the severe winter conditions of 1955–56. Five of these have shown considerable promise in respect of other agronomic features and are earmarked for inclusion in replicated trials.

FORAGE KALES AND RAPES

During the past 20 years the acreage of forage kales and rapes grown by the British farmer has increased approximately three-fold. Although valuable in the farm economy, as is evident by this rapid expansion, these crops suffer from numerous limitations, notably the lack of hardiness of the higher yielding types. It is, therefore, gratifying to report that with additional facilities made available at Plas Gogerddan, and the appointment of T. D. Johnston to the staff, it became possible in 1955 to commence breeding investigations on this important group of forage plants.

Kale is a high yielding crop intended chiefly for dairy cattle and is increasing in importance at the expense of other root fodder crops. The aim of the work pursued by Johnston is to breed leafier, disease resistant and more productive types suited to modern agricultural conditions and of sufficient hardiness to enable them to be utilized through the winter up to the time that the early grass becomes available. Rape, on the other hand, is a short-duration crop widely grown on the upland and marginal farms of Wales for feeding in autumn and early winter. Its obvious defect is again lack of hardiness and susceptibility to a number of pests and diseases, especially club-root disease (*Plasmodiophora Brassicae*).

The Station has had only one full season's experience with these crops, and one of the first tasks undertaken was the assessment of the relative agronomic merits of available strains and closely related types. In May, 1955, the first of a series of agronomic trials was laid down consisting of 9 strains of Marrow Stem Kale, 16 of Thousand Headed Kale and 11 of Hungry Gap Kale and Rape-Kale derived mainly from commercial sources in the United Kingdom and France.

As a result of the abnormally dry summer of 1955 the general level of yields was low and severe attacks of swede midge (*Contarinia*

nasturtii) and mildew (*Erysiphe polygoni*) caused considerable loss of plants in the Hungry Gap Kale and Rape-Kale. The Marrow Stem Kales were harvested in mid-November and the Thousand Headed Kales in February, 1956, to determine the yields, leafiness, dry matter and crude protein contents of the strains.

The accompanying table shows some of the results obtained for 5 strains each of Marrow Stem and Thousand Headed Kales.

Kales	*Yield in tons per acre*	*Percentage leaf*	*Yield of dry matter in cwt. per acre*
Marrow Stem (cut 14.11.55)			
Commercial strain (a)	11.2	44	33
,, ,, (b)	12.0	52	34
,, ,, (c)	10.0	39	30
,, ,, (d)	10.1	53	32
N.Z. medium Chou Moellier	9.1	56	26
Strain differences	N.S.	±1.61	N.S.
Thousand Headed (cut 7.2.56)			
Commercial strain (a)	6.92	70	22
,, ,, (b)	7.86	71	26
Canson Kale	7.02	80	23
Chou de cholet	9.88	64	30
Chou fourrager blond	9.00	57	24
Strain differences	N.S.	±1.37 Sig.(P = 0.05)	N.S.

As shown above the differences in yield between the 5 strains of Marrow Stem Kale were not significant although real variations in leafiness were indicated. The Thousand Headed Kales, on the other hand, did show much greater variation, certain strains of foreign origin approaching the Marrow Stem Kale in bulk of green material produced whereas the British types gave only two-thirds of this amount. Differences in morphological type, winter hardiness and disease resistance were also more evident in this group.

Canson Kale, a dwarf Thousand Headed type, showed considerable promise because of its very leafy, low-growing habit, extreme hardiness, and lateness to flower in spring. Plants of this type have been selected for an investigation into the possibility of using hybrid vigour in the production of kales. Self-pollinated seed from a number of randomly chosen plants was sown in the spring

of 1956 for study of the first generation inbreds and subsequent use of these in hybridization experiments.

During the period under review progress was made in the development of suitable techniques for handling, under greenhouse conditions, plants selected from the field for breeding purposes. A small number of preliminary hybridizations and selections from within commercial stocks of kale were also made.

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GRASSLAND AGRONOMY

By Ll. Iorwerth Jones

Early agronomic investigations

The early investigations with herbage plants at the Station showed that quite apart from the need for breeding better strains there were many other problems in grassland improvement awaiting elucidation. In the period between the two wars (1919–39) therefore a wide range of agronomic investigations was conducted on a variety of soils ranging from good lowland to poor hill land, which included studies into the establishment, persistency, annual and seasonal productivity of different types and species of herbage plants as well as the interaction between the constituents of the sward. Studies were also pursued on the influence of management and manuring on the total and seasonal yield of herbage, its botanical and chemical composition, and the relative feeding value of contrasting types of pastures. At the same time new techniques suitable for investigating grassland problems were evolved and tested. The results obtained proved of immense value in the successful reseeding of land ploughed for arable crop production as well as in the improvement of large acreages of poor permanent pastures.

Towards the end of World War II and in the immediate post-war period, it was realized that the farming community was becoming strain conscious in regard to herbage plants ; the number of strains of herbage plants was gradually increasing by reason of introductions from overseas and continued efforts by plant breeders in this country. The difference between these strains was less obvious than that between the commercial seeds and the bred strains which were available before the war and therefore critical tests based on production were needed in order to assess their relative values.

The real criterion of the value of any herbage plant is its capacity to supply the grazing animal's needs for the production of meat, milk and wool, but the amount of land required to conduct such trials, to compare all strains and combinations of strains under a variety of conditions, is prohibitive.

In view of this an attempt was made in 1945 to draw up a scheme of testing which reduced the need of using the animal as a yardstick, at least in the early stages of testing, and this scheme forms the basis of our present strain testing technique.

The scheme is based on the assumption that the relative value of herbage plants is not constant ; it may vary because of differing

environmental conditions such as climate, soil fertility and system of management including the intensity of grazing and manuring, as well as the purpose for which the strain is to be used, e.g., hay, silage, early spring growth, bridging the summer gap or providing green herbage for grazing *in situ* in late autumn and winter.

Scheme of strain testing

The scheme adopted at the Welsh Plant Breeding Station in the past 10 years consists of three parts, each of which provides specific information. The actual procedure, however, varies according to the character of the plant. The following is a brief outline of the three stages.

The preliminary trials generally consist of a large number of small plots (1/1000–1/200 acre) designed to survey the potentiality of the strain over a wide range of environmental conditions and thereby indicate its usefulness or limitation in relation to other species or strains. Evidence is provided regarding the establishment of the plant from seed and its capacity to form a sward, the ability of the strain to associate with other plants in a sward, its behaviour in regard to persistency, winter " burn " and disease resistance ; its annual and seasonal production of herbage, and the influence of management, manuring, etc., on herbage production.

Most of the data consist of eye observations and estimations, and although not based on critical yield data they are extremely useful in that they give an indication of the place and value of the strain without resorting to the more laborious methods.

Strains which have shown promise in preliminary trials receive further study in more critical herbage production trials under the conditions for which they have shown most promise : they are then grown alongside the established strains in sward plots ranging in size from 1/100 to $\frac{1}{4}$ acre depending on the method of management and the type of stock used for grazing. The plots are sampled regularly throughout one or more seasons to compare the annual and seasonal production of herbage as well as the botanical and chemical composition. When the management involves grazing the animal is used only as a defoliating machine, each plot being grazed separately and as far as possible to the same intensity. These trials involve careful management of the grazing stock and a great deal of sampling by hand to obtain an accurate measure of the herbage.

Ideally the most productive strains in the herbage production trials should be compared in animal production trials. These, however, involve a large area of land and the number of trials

which can be conducted is limited. Such trials, therefore, are confined in the main to comparing swards differing markedly in botanical composition, swards involving the assessment of a strain of a species not normally included in agricultural seeds mixtures, or to a comparison of swards receiving different manurial treatment and management. The assessment and comparison of strains of the same species and of similar character are therefore based chiefly on the herbage production data.

Preliminary trials

Establishment. Observations from a number of trials conducted during the period 1950–1956 showed that Italian and perennial ryegrasses established well and formed dense vigorous swards soon after sowing and generally checked the growth of annual weeds during the seeding year.

Cocksfoot, timothy and meadow fescue made less vigorous growth in the seeding year, and suffered some damage from competition by annual weeds. Satisfactory establishment was obtained in all trials at the Station but timothy failed to establish in some extension trials, owing to suppression by volunteer grasses.

Meadow foxtail made slow growth in the seeding year and suffered considerable damage from competition by unsown species ; it produced fair swards in succeeding years but always contained a considerable proportion of unsown grasses and weeds.

Tall fescue gave variable results. In one trial sown on heavy land on Lane Field, Frongoch, in 1950, it made poor growth in the seeding year and failed to form a satisfactory sward in the following spring. In six other trials it formed full swards in the first harvest year despite its slow growth in the seeding year. In one trial thin swards followed a seeding of 10 lb. and 20 lb. per acre respectively whilst a seed rate of 30 lb. formed a full sward. The inclusion of Italian and perennial ryegrasses as companions in broadcast stands reduced the establishment of tall fescue, whereas cocksfoot and meadow fescue had only a small influence. The establishment of tall fescue was better when sown in alternate narrow drills than when sown broadcast with companion grasses.

A hybrid strain of *Phalaris* (S.230) failed to establish on heavy land in 1950 but produced a full " take " on another area in 1952.

Agrostis tenuis (Br 616), in spite of low establishment and poor growth in the seeding year, normally formed a dense sward in the following year. In one trial a seeding of 12 lb. formed a complete cover of grass within three months of sowing ; at a low seed rate of

1 lb. per acre the sward was very thin and patchy in the autumn of the seeding year, yet by the following autumn it had a dense growth of *Agrostis* over the whole area.

White clover was sown in all trials at the rate of 2 lb. per acre. The "take" and spread of clover varied from species to species and from one strain to another of the companion grass. The best "take" of clover was obtained with timothy and grasses which made the least growth when in the seedling stage. It was noticeable that on the *Agrostis* swards white clover produced an excellent stand and made good growth on areas where the *Agrostis* was extremely thin, but as the sward filled up the clover became scarce. Within twelve months of sowing at the rate of 12 lb. per acre the *Agrostis* had virtually suppressed the white clover.

Persistency of strains when sown in simple mixtures of one grass with white clover. S.22, Irish Italian ryegrass and H1 Short Rotation ryegrass each with white clover were compared in a grazing trial commenced in 1950 (A.H.C.). The swards were grazed by sheep on a rotational basis, and all grass strains persisted for three harvest years. During the third season the production of S.22 was equal to that of adjoining perennial ryegrass swards and contained less than 13 % of unsown species. In the cold weather experienced in February 1954 the three strains suffered very high plant casualties, especially H1 and Irish Italian ryegrasses.

In each of the three swards it was noticeable that the highest number of plant casualties in each strain occurred on the areas carrying the greatest bulk of autumn growth, whereas on those carrying a relatively small bulk of herbage casualties were far fewer. A similar phenomenon was observed on a sward of S.24 perennial ryegrass, which indicates that ryegrass swards entering the winter with an abundance of herbage in a "winter proud" condition are liable to suffer more plant casualties during a severe winter than those which are relatively short and well grazed.

Persistency of strains when sown in mixtures with companion grasses. In a number of trials, seeds mixtures containing two grasses and white clover have been sown ; in some the two grasses were of different species whereas in others the two strains were of the same species. Many of the grasses included in these trials, although relatively persistent in a simple one grass/one clover mixture, were far less persistent when grown with a companion grass. In general, however, one or other of the two grasses dominated the sward, thereby reducing the persistency of its companion grass. In a 10-year-old sward Danish cocksfoot contributed 10% of the herbage

as companion with Irish perennial ryegrass ; its contribution when grown with S.23 was negligible. On the other hand S.23 perennial ryegrass persisted far better in association with Danish cocksfoot than with S.26 cocksfoot.

On Middle Field, Brynamlwg, *Agrostis tenuis* (N.Z. brown top) was sown in 1952 in association with white clover and S.23 or S.24 perennial ryegrasses. The plots were subjected to grazing management and received three manurial treatments, viz., no manures after seeding ; lime and slag early in spring of the first year ; lime and slag in spring of the first year followed by regular dressings of a compound fertilizer. During the first harvest year (1953) there was little difference in the composition of the swards except that the compound fertilizer increased the ryegrass component in each mixture. During the second and third seasons ryegrass and *Agrostis* were present in about equal amounts on the unmanured area ; ryegrass was more plentiful than *Agrostis* on the areas which received lime and slag, whereas on the heavily fertilized area the sward was mainly composed of perennial ryegrass, the *Agrostis* contributing less than 5% to the total herbage. S.23 ryegrass was more aggressive than S.24 towards *Agrostis* at all fertility levels, but this was most marked on the areas receiving no fertilizers, i.e., the lowest fertility level.

In his report on the herbage production of two strains of perennial ryegrass, Hughes (1955) showed that the contribution of Italian ryegrass in grazed swards was greater when grown with Irish than with S.24 perennial ryegrass. Italian ryegrass also thrived better on swards receiving regular applications of nitrogen than those receiving none. The data, summarized in the following table show the decline in the contribution of Italian ryegrass to the total herbage from the first to the fifth harvest years :

Persistency of Italian ryegrass as measured by its percentage contribution to the total herbage production

		Italian ryegrass with			
		S24		*Irish*	
Harvest	*Year*	*— Nitrogen*	*+ Nitrogen*	*— Nitrogen*	*+ Nitrogen*
First	1948	35	40	51	54
Second	1949	8	17	34	58
Third	1950	3	6	11	22
Fifth	1952	1	2	7	11

In a separate experiment on the production of grass for conservation as silage or dried grass (I.D.) it was found that whilst Italian ryegrass had persisted well into the third harvest year on the areas where no companion plants had been included, it was almost completely suppressed when sown in conjunction with tall fescue and meadow fescue, and in particular by perennial ryegrass. This is illustrated by the following figures regarding the relative density of the Italian ryegrass in different mixtures during the third harvest year (1952) :

Companion grass	*Relative values for Italian ryegrass*	
	Tiller density	*Yield*
Italian ryegrass sown alone	100	100
,, ,, + timothy	34	49
,, ,, + cocksfoot	22	42
,, ,, + tall and meadow fescues	4	24
,, ,, + perennial ryegrass	3	11

Influence of one strain on another of the same species (A.H.C.). Strains of perennial ryegrass were grown in simple mixtures of one strain/one clover as well as in more complex mixtures involving two strains of ryegrass with clover, e.g., S.23 + S.24 + white clover or S.23 + Irish + white clover.

The ryegrasses in the simple mixtures formed a full sward for a number of years but in complex mixtures S.23 in the third harvest year was the dominant strain in the grazed swards, particularly the hard grazed hill swards and in those based on S.23 plus Irish perennial ryegrass. A random selection of ryegrass tillers was taken from these swards and propagated as spaced units to assess the proportion of each strain in the sward. The results for swards at two centres are shown by the following figures :

	S.23 tillers as a percentage of total ryegrass tillers in swards of	
	S.23/Irish	*S.23/S.24*
Lowland centre—5th harvest year (rotational grazing)	95	72
Upland centre—6th harvest year (continuous hard grazing)	99	97

Winter " burn ". Evidence was obtained regarding the ability of herbage plants to maintain their green colour in the winter months particularly during the cold weather experienced in February 1954, 1955, and 1956. In almost all cases the *S* strains of cocksfoot were more winter green than Danish cocksfoot ; S.22 and Irish Italian resisted the extreme cold periods better than H1 Short Rotation ryegrass, whilst S.24 suffered less " burn " than the New Zealand Certified Mother perennial ryegrass.

In an experiment to compare *Agrostis tenuis* and timothy, marked differences were observed in their ability to maintain their winter greenness. Two strains of timothy, S.48 and S.50, and two of *Agrostis*, N.Z. brown top and Br 616, a strain selected at the Welsh Plant Breeding Station, were included in the trial. After the first November frosts in 1954 the N.Z. brown top was the only grass showing marked winter " burn ", the amount gradually increased during the winter, and none of the strains escaped damage. Samples of herbage taken early in February 1955, showed that all the grasses had suffered, but the damage varied considerably ; this is shown by the following figures :

	Winter " burn " as a percentage of the total herbage (Feb. 1955)
Agrostis tenuis (N.Z. brown top)	70
,, ,, (Br 616)	40
S.48 timothy	15
S.50 ,,	5

Further cold weather caused still more damage, so that by the middle of March the two *Agrostis* strains were completely brown and there was hardly a trace of green in the leafage. The timothy plots, on the other hand, were still remarkably green, particularly S.50. Samples of the latter taken during late March showed a yield of 1900 lb. per acre of dry matter almost free from leaf " burn ".

Herbage production studies

During 1950–56 herbage production data were collected from several trials for the study of total annual and seasonal growth over a number of years. The trials included different species and strains of grasses sown in simple one grass/one clover mixtures as well as in more complex mixtures consisting of two species or two strains of the same grass species plus clover. In most of the trials

sheep were used as defoliators, each plot being grazed independently on a rotational basis. In some trials data were taken from plots normally subjected to continuous grazing. In others the grazing animal was excluded, emphasis being placed on the production of herbage suitable for conservation as dried grass, silage or hay. Studies have also been made regarding the behaviour and relative herbage production of a number of grasses when subjected to different systems of defoliation and manuring. Some of the more important findings derived from these studies are discussed below.

Herbage production under grazing management. This trial, sown in 1947, and conducted by Roy Hughes (now of Hill Farming Research Organisation, Edinburgh) was designed to study the behaviour and herbage production of S.24 and Irish perennial ryegrasses in relatively simple mixtures, with and without nitrogenous fertilizers. A full report of the trial has already been published (Hughes, 1955). A brief discussion of the results obtained under grazing management in the fifth harvest year (1952) is presented here.

Although the total yield of herbage in 1952 was similar for the S.24 and Irish mixtures (S.24 = 100, Irish = 97), there were considerable differences in seasonal production and in the botanical composition of the herbage. The mixtures containing S.24 produced 24% and 16% more herbage than the Irish ryegrass mixtures in the spring and autumn periods respectively, but 7% less herbage in the May to August period.

The yield of the perennial ryegrass component of the swards and its percentage contribution to the total yield of herbage showed a marked difference between the two strains as indicated by the figures below. Throughout this Report yields are based on dry matter per acre.

	Yield of perennial ryegrass (*cwt. per acre*–1952)		*Percentage contribution of perennial ryegrass to the total yield* (1952)	
	S.24	*Irish*	*S.24*	*Irish*
No nitrogen	52.9	27.0	77	40
Nitrogen (102 N.lb. per acre)	71.4	27.1	73	28

Italian ryegrass was included in one seeds mixture with S.24, and in one with Irish perennial ryegrass. Its production in the fifth harvest year was relatively low in all mixtures ; the data obtained demonstrate its poorer production in the S.24 mixtures, and also

that its ability to withstand the aggression of other species was increased by the application of nitrogenous fertilizers. These points are illustrated by the following figures :

	Yield of Italian ryegrass (cwt. per acre)	
	S.24 mixture	*Irish mixture*
No nitrogen	0.7 (1%)*	4.8 (7%)*
Nitrogen (102 N.lb. per acre)	2.0 (2%)	11.1 (11%)

*Figures in brackets indicate the percentage contribution of Italian ryegrass towards the total yield of herbage.

A trial designed to compare the annual herbage production, particularly in early spring, of six strains of grasses each sown with S.100 white clover (A.H.C.) was sown in July, 1950. The grass strains were S.22, Irish Italian ryegrass, H1 Short Rotation ryegrass, S.24, N.Z. perennial ryegrass C.M., and S.55 meadow foxtail. All the plots were grazed independently by sheep on a rotational basis, and 3 cwt. of nitrogenous fertilizer applied in March of each year. During the first three harvest years all strains (except meadow foxtail, which was only a fair sward) maintained full swards, but following the extreme cold which prevailed during February 1954, the Italian ryegrasses and the H1 Short Rotation suffered considerable plant casualties and herbage production was severely reduced.

The following figures indicate the relative herbage production of the different species during the first three harvest years (1951–53) :

	Meadow foxtail	*Perennial ryegrass*	*Italian ryegrass**
Average annual yield (cwt. per acre)	76.8	87.1	80.8
Relative annual yield	88	100	93
Average spring yield (cwt. per acre)**	9.5	11.5	13.5
Relative spring yield	70	85	100

* H1 Short Rotation ryegrass included in this group

** Sampled first week of April

The relative annual production of the Italian ryegrasses in the first three harvest years is shown by the following figures (S.22=100):

	Annual yield	*Spring growth*
S.22 Italian ryegrass	100	100
Irish Italian ryegrass	93	99
H1 Short Rotation ryegrass	101	86

The data also showed that the production of S.22 relative to that of the other two strains improved from the first to the third year, in fact the annual production of S.22 in the third year was equal to that of the perennial ryegrasses.

Following plant casualties caused by the cold weather in February 1954, all three strains made poor growth. They improved during 1955 and 1956, but apart from S.22 their production was still low. In 1956, although the annual herbage production of the S.22 sward was considerably lower than that of the perennial ryegrasses and the meadow foxtail, it produced an equal growth of herbage for the first grazing in the middle of April.

Data collected in March and April 1952, indicate that H1 grows more rapidly than S.22 during relatively mild weather, whilst S.22 was far more vigorous in the cold spells.

During the six harvest years of this trial the ryegrass production of the swards formed by S.24 and N.Z. perennial ryegrasses was almost identical, but the latter swards produced 7% more white clover and nearly 30% more unsown grasses.

The performance of swards composed of meadow foxtail was generally poorer than those consisting of perennial ryegrass in annual yield and in spring growth. During the wet season in 1954, however, following the cold spell experienced in February, their performance was slightly better in terms of annual production and far superior to the perennial ryegrass swards in spring growth.

Data collected during the 1953–54 winter illustrate the influence of extreme cold wintry weather on the herbage of different species. Swards sampled in December 1953, and also in March 1954, showed that a considerable proportion of the December herbage on Italian ryegrass plots disappeared during the cold spell, whereas that on the meadow foxtail plots appeared to be less affected. This is illustrated by the following figures :

	Yield of herbage in cwt. per acre		
Date of sampling	*Meadow foxtail*	*Perennial ryegrass*	*Italian ryegrass*
14.12.53	8.6	10.1	8.7
5.3.54	6.9	5.0	3.0
Percentage loss of herbage between 14.12.53 and 5.3.54	20%	50%	65%

In another trial sown in July, 1950 (A.H.C.), the herbage production of S.23, S.24, S.101 and Irish perennial ryegrasses was compared when grown in swards of one grass strain with white

clover as well as when combined in the following mixtures, S.24/Irish; S.23/Irish; S.23/S24 and S.23/S.101. All plots were grazed independently five or six times a year on a rotational basis and data regarding the yield of herbage and its composition were taken prior to each grazing.

Although the full analyses of the data have not been completed the following trends have been observed:

(1) S.23 was more persistent than S.101 and S.24; Irish perennial ryegrass the least.

(2) Persistency of both S.24 and Irish ryegrasses was reduced when sown in combination with S.23.

(3) The difference in total yield of herbage produced by the various swards was small and in general the "one strain" mixtures produced as much herbage as the "two strain". The S.23/S.101 mixture, however, was less productive than either the S.23 or the S.101 swards.

(4) Although the annual yield of herbage was similar, the yield of ryegrass was much lower in the Irish ryegrass swards after the first harvest year, especially in the sixth harvest year (1956). On the other hand white clover, and particularly the unsown species, substantially increased their contribution towards the total yield of the Irish ryegrass swards. This is illustrated by the botanical composition of the herbage produced in 1956 as shown by the following figures:

	Percentage botanical composition of swards based on weight of herbage produced in the sixth harvest year		
	S.23	*S.24*	*Irish ryegrass*
Perennial ryegrass	81	73	37
White clover	11	13	19
Unsown species	8	14	44

(5) The yield of herbage on the different swards was similar in March, but when stem elongation of the early flowering S.24 and Irish ryegrasses commenced, their subsequent growth was more rapid than that of the later flowering S.101 and S.23.

(6) S.101 ryegrass was not as resistant to frost and wet conditions as S.23 ryegrass. Its yield in May was generally higher than that of S.23 but apart from this period S.23 was generally more productive than S.101.

(7) After the May grazing the contribution of the ryegrass in

the S.23 swards was greater than that of the other ryegrass strains, but herbage production was similar because of the higher yield of clover and unsown species.

(8) During the earlier years of the trial, although the total yield of herbage was similar for all swards, those composed of a mixture of early- and late-flowering ryegrasses produced a more uniform distribution of growth over the season. In later years, however, this difference disappeared due to the dominance of one strain over its companion in the mixture.

(9) The yield of herbage varied considerably from year to year, but there was little, if any, indication of a reduction in the annual herbage production of most of these swards during the six years.

A trial to study the herbage production of five strains of timothy, three of meadow fescue, two of tall fescue and S.23 perennial ryegrass when sown in simple mixtures of one grass plus clover, and in more complex mixtures containing one or more strains of timothy with one or more strains of meadow fescue, was sown in 1949 (Ll. I. J. *et al.*).

All plots were grazed independently by sheep on a rotational basis, but during the first year a silage cut replaced one grazing. Data on yield of herbage and its composition were taken during the first five years.

In the first three years tall fescue outyielded all other species in total herbage, sown grasses and unsown species, but produced the lowest yield of white clover. In addition, apart from the first year (1950), its growth in early spring was far greater than that of any other mixtures and it provided grazing one month earlier. The S.23 perennial ryegrass mixture, on the other hand, produced less total herbage than either timothy or meadow fescue mixtures although it gave similar yields of sown grass. Unsown grasses, weeds and clover contributed more to the timothy and the meadow fescue mixtures than to the S.23 perennial ryegrass mixture. This is illustrated by the following figures :

	Relative yield for 1950–1952			
	Total herbage	*Sown grasses*	*White clover*	*Unsown species*
Tall fescue	100	100	58	100
Meadow fescue	97	92	92	76
Timothy	96	85	100	87
S.23 perennial ryegrass	85	90	74	30

A comparison of the timothy swards shows that in the first three years S.51 produced the greatest yield of timothy, but because of the greater yield of white clover, unsown grasses and weeds in the other timothy swards the total production of herbage was similar for all strains.

In comparing the yields of meadow fescue it was found that all three strains were similar in total yield of herbage, but whereas S.53 gave the greatest yield of meadow fescue, the Danish meadow fescue swards produced larger amounts of white clover and unsown species. A similar trend is also found in tall fescue ; Alta and S.170 produced similar amounts of total herbage, but the S.170 plots gave more tall fescue but less clover and unsown species.

Nine seeds mixtures in this trial contained both timothy and meadow fescue. In the first harvest year the contribution of the two species was similar but during the next two years that of timothy was considerably reduced whereas the meadow fescue increased markedly. The decrease in timothy and increase in meadow fescue were more marked in the mixtures containing S.53 than S.215 meadow fescue, and in those containing Canadian, or S.51 than S.48 timothy.

The timothy/meadow fescue swards produced less total herbage than either the meadow fescue or the timothy swards in the first two years, due to a smaller yield of clover and unsown species. In the third season the yield of the sown grasses from the meadow fescue/timothy swards was greater than the average of the timothy and meadow fescue grown separately, but because of the much smaller yield of the unsown grasses and clover in the former, the total yield of herbage was similar.

The field was ploughed in February 1955, and arable crops were sown in strips across each plot to determine the influence of the previous swards on the production of succeeding crops. No fertilizers were applied. Appreciable differences in vigour, colour and general appearance of the crops were observed throughout the growing season, indicating the presence of considerable residual variation in the available nitrogen in the soil. The crops following S.50 timothy, S.170 tall fescue, and to a lesser extent S.48 timothy, appeared paler in colour during the growing season, and on the former plots the yields of grain and kale were 86% and 45% respectively of the average yield obtained following the other swards on this field. It is interesting in this connection to refer to the white clover yields which were obtained on some of these swards in the year preceding ploughing up. These were as follows :

	Yield of white clover in lb. per acre
S.50 timothy	103
S.170 tall fescue	305
S.48 timothy	469
Alta tall fescue	520
Other timothy spp.	623

Herbage production for conservation. A number of trials have been conducted to study the behaviour of different species and strains of grasses when subjected to regular mowing in the absence of the grazing animal ; these were concerned with the production of herbage suitable for conservation as silage or dried grass.

Owing to the absence of the grazing animal heavy applications of artificial fertilizers were given each season, amounting to 10–15 cwt. nitrochalk, 4–5 cwt. superphosphate and 2–5 cwt. muriate of potash or their equivalent in compound fertilizers. A proportion of the fertilizers was applied in early spring and after every cut, but in some specific cases fertilizer was withheld and confined to particular periods of the year

In one of these trials started in April 1949, (I.D.), each of twenty strains of six grass species was sown in combination with (i) white clover, (ii) white and red clovers and (iii) white and red clovers plus Italian ryegrass.

The average annual production of all plots over a three-year period was 8,280 lb. dry matter per acre, containing 14.7% crude protein giving a protein production of 1,220 lb. per acre.

The yields of dry matter in the first and third harvest years were similar but the botanical composition had changed ; the clovers had almost disappeared and unsown species had more than doubled by the third year.

The addition of red clover, or red clover plus Italian ryegrass, to the grass plus white clover mixtures had no appreciable effect on the total yields of dry matter or crude protein over the three-year period. The data for the individual years show that the superiority of the Italian ryegrass/red clover mixture was confined in the main to the first harvest year, and that the clover mixtures, particularly those based on white clover, were more productive in the third harvest year. The total yields of herbage and crude protein in the white clover mixtures were 10% higher, and in the Italian ryegrass/clover mixtures 10% lower in the third than in the first harvest year.

Data regarding the relative production of the different grasses are interesting, but too complex for detailed consideration in the present Report because of the variations in seasonal growth and fertilizer treatments, e.g., the early-growing tall fescue and Italian ryegrass allowed of more cuts per annum and received more frequent applications of nitrogenous fertilizers than other species, particularly timothy. The highest total yield of herbage was given by the tall fescue and the Italian ryegrass swards, the former containing 15.7% and the latter an average of 14.2% crude protein. The lowest yields of dry matter and crude protein were given by the meadow fescue and perennial ryegrass swards. Timothy produced almost as much dry matter as the tall fescue and Italian ryegrass mixtures.

Although the same amount of Italian ryegrass seed was sown with each of the different grasses in the Italian ryegrass/clover mixtures, its production varied from one associate grass strain and species to another; the degree of suppression of the different strains and species by the Italian ryegrass also varied. These two aspects are shown by the following figures for the third harvest year, 1952.

Yield (cwt. per acre) of sward components in the third harvest year

	Italian ryegrass + companion			*Companion grass grown without Italian ryegrass*
Companion grass	*Italian ryegrass*	*Companion grass*	*Total*	
Canadian timothy	30.4	23.2	53.6	54.5
S.48 ,,	16.1	46.4	62.5	64.3
S.215 meadow fescue	14.3	45.5	59.8	61.6
S.170 tall fescue	6.2	53.6	59.8	70.5
S.24 perennial ryegrass	3.1	47.3	50.4	50.0

During the first harvest year the Italian ryegrass reduced the production of S.215 meadow fescue by 77%, Canadian timothy by 57%, and S.24 perennial ryegrass by only 9%.

Further experiments were laid down in 1952 (I.D.), to study the effects of time of cutting, number of cuts and fertilizer treatments, including time of fertilizer application, on the production and behaviour of a number of grass species and strains. Some of the results of these studies are briefly considered below.

The influence of the time of application of nitrogenous fertilizers on herbage production. In this investigation the swards during the season

were mown five times at intervals of five weeks ; nitrogenous fertilizers were applied at a uniform rate to each plot after every cut. The plots were divided into three groups, the fertilizer being applied (i) immediately the herbage was cut, (ii) 10 days after cutting, and (iii) 25 days after cutting.

The delay in applying the nitrogenous fertilizers on S.51 timothy reduced the dry matter yield to a slight extent but caused a marked increase in the percentage and yield of crude protein. In S.143 cocksfoot, on the other hand, the delay caused a marked decrease in the yield of dry matter, a marked increase in the percentage crude protein but a decrease in the total yield of crude protein.

Data collected in the third harvest year (1955) showed how the dry matter yield of grasses was affected by the time of fertilizer application in relation to the date of cutting :

	Fertilizer applied.		
	(*i*) *Immediately after each cut*	(*ii*) 10 *days after each cut*	(*iii*) 25 *days after each cut*
S.51 timothy	100	101	89
S.23 perennial ryegrass	100	98	91
S.24 ,, ,,	100	93	80
S.170 tall fescue	100	88	80
S.143 cocksfoot	100	92	79
S.22 Italian ryegrass	100	84	77
Average	100	93	83

In another experiment a comparison was made of the influence of regular applications of nitrogenous fertilizers throughout the growing season, with applications confined to early spring, late summer and autumn, the same quantity of nitrogen being applied per season. After three years (1953–55) it was observed that the regular application had reduced the yield of clover. In the following season (1956) all plots were treated alike—no nitrogenous fertilizers were applied. The influence of the treatment in the previous three years on the production of herbage in midsummer of 1956 is shown by the following table (average of Italian ryegrass and meadow fescue swards) :

	Yield of herbage (lb. per acre) on 18.7.56		
Nitrogen application 1953–55	*Total*	*Grass*	*White clover*
Applied throughout the season	1030	700	330
Applied in early spring, late summer and autumn*	1510	790	720

*No nitrogenous fertilizers applied in May, June or early July.

Influence on herbage production of time of cutting in relation to stage of growth. A great deal of evidence is being collected on the ability of various strains of timothy to recover after being cut at different stages of growth. The data from this experiment show that when defoliation of the herbage involves merely a removal of vegetative portions of the plant without damaging the stem apices each tiller is still capable of further immediate active growth, but when defoliation involves the removal or injury of the stem apex of a tiller, that tiller is incapable of further growth and the buds at the base are stimulated to develop. However, the growth of these basal buds is slow compared with that of well-developed tillers which have not suffered injury to their growing points.

This is illustrated by reference to the growth of American timothy between 22 June and 18 July 1956, on two series of plots:

	Yield of herbage (lb. per acre) produced between 22 June and 15 July 1956
Series 1 — regrowth following a first cut taken on 22 June, with removal of all stem apices	440
Series 2 — regrowth following a second cut taken on 22 June, most of the stem apices had been removed in the first cut on 15 May.	1070

Further evidence on this phenomenon is provided by data regarding the recovery growth of an early-flowering timothy (American) and a late-flowering timothy (S.51) following their defoliation on 15 May and 15 June 1954. On 15 May almost all the stems of American timothy, but only a few of the S.51, had elongated sufficiently for the stem apices to be removed by the mower. During the following month, 15 May to 15 June, the recovery growth of S.51 was mainly the regrowth of the cut tillers whereas in American timothy most of the new growth consisted of new shoots growing from the base of the plant. Their relative herbage production as measured by the second cut taken on 15 June was S.51 = 100, American = 53. In the cut taken on 15 June the herbage of S.51 was chiefly elongated shoots and the growth 15 June–19 July con-

sisted of the development of new basal buds ; in American timothy few of the new shoots had elongated by 15 June and the growth between 15 June and 19 July was mainly the regrowth of the cut tillers. Their relative herbage production between these two dates was S.51=100, American=133.

Technique studies on herbage assessment. These studies, which relate to the influence of management on the relative production of different grasses, are designed to assess how far the results obtained under one system of management are applicable to another, e.g., do results obtained under a regular cutting system apply to swards grazed at equivalent periods of time ? In conducting these investigations attention has also been given to the influence of the method of herbage sampling on the determination of herbage yield.

Experiments to compare the production of herbage of strains and potential strains of cocksfoot under different systems and intensities of defoliation and fertilizer application, were laid down in 1952 (I.D., A.H.C.). The management included (a) rotational grazing with sheep, five grazings per season, (b) mowing of herbage five times per season, (c) mowing of herbage for hay followed by two cuts of aftermath, and (d) mowing of herbage five times per season followed by liberal application of fertilizers. It was arranged that the mowing in section (b) coincided in time with the grazing of section (a). Sections (a), (b) and (c) received 3 cwt. of a compound fertilizer (12, 12, 15) during the first week in September of each season, and section (d) received a total of 6 cwt. nitrochalk, 8 cwt. compound fertilizer (12, 12, 15) and 2½ cwt. muriate of potash per annum, part of which was applied after each cut.

The data show that when the different cocksfoot swards were defoliated simultaneously and the same number of times in a season their relative production of herbage under the different systems varied, the S strains being more productive than Danish cocksfoot when subjected to grazing, whereas Danish generally produced more herbage than the S strains when the swards were mown.

This experiment illustrates the danger of utilizing data collected under one system of management to provide information on the relative production of strains under another system, e.g., the yields obtained from swards regularly mown may not indicate the true relative production of those swards when subjected to grazing.

A further analysis of the data obtained suggests that the differences referred to above are partly due to the influence of the

management on the sward and partly to the height at which the samples are cut. Compared with sheep grazing the mowing machine leaves a greater amount of herbage on the plots even when fitted with low cutting attachments. Some strains are dense and prostrate, others form a taller and less dense sward, the height of cutting, therefore, is an important factor when sampling swards. This is illustrated by the data obtained in April 1953, when the swards were first sampled and all areas had received identical managements since sowing the previous summer. The mown plots were sampled by an autoscythe and the grazed plots by garden shears which cut much nearer the soil surface. The following figures for two strains of cocksfoot show the yields of herbage obtained by the two methods of sampling :

	Yield of cocksfoot in lb. per acre April 1953	
	Danish	*S.*143
(*a*) Cut with hand shears	1136	1226
(*b*) ,, ,, autoscythe	977	482
Yield of (b) as percentage of (a)	86%	39%

Another experiment (D.G.M.) was designed to study the behaviour and production of swards composed of different species and strains of grasses when subjected to different treatments. Five swards were based on one grass plus white clover, the grasses being S.24 perennial ryegrass, S.23 perennial ryegrass, S.22 Italian ryegrass, S.48 timothy, S.26 cocksfoot ; the sixth was based on a mixture of these five grasses. The seeds mixtures were sown in June 1955, and the resultant swards treated uniformly throughout the summer and autumn of the seeding year. During the following winter each sward was divided into six sub-plots and thereafter received different treatments. Three of the sub-plots were regularly grazed with sheep and the remaining three were mown on the same date as the grazings took place. Of the grazed plots one received the natural return of dung and urine, one received no dung or urine and on the third the dung and urine were collected and distributed uniformly after sampling to determine their chemical composition. Of the mown areas, one received no dung or urine, the other received the calculated dung and urine it would have received had the herbage been consumed, and the third received artificial fertilizers containing the equivalents of nitrogen, phosphate, potash and lime.

During the first harvest year (1956) the production of herbage varied considerably from one treatment to another, but the pattern of the response was similar for all seeds mixtures. There was, however, a marked difference in the magnitude of the response ; S.26, S. 22 and S.24 showing the greatest response to treatment and the complex mixture the least. The data also show that S.22 and S.26 yielded slightly more herbage on the mown plots than on the grazed plots ; all other swards produced more herbage on the grazed plots.

Animal production trials

Small plot trials conducted during 1947–1954 had shown that S.170 tall fescue swards, once they were fully established, produced a high yield of herbage annually and in particular more early spring growth than most perennial herbage plants, being earlier than the early-flowering perennial ryegrasses.

In August 1954, an animal production trial (Ll. I. J.) was sown with S.24 perennial ryegrass and S.170 tall fescue each with white clover to assess the relative values of these two strains as food for farm stock. From April to September/October 1955 and 1956, the swards were grazed by yearling cattle on a rotational basis, and during the winters ewe lambs grazed the late autumn growth.

The data obtained on herbage production support previous observations in that the seedling growth of S.170 is much slower than that of S.24 perennial ryegrass. This difference extended to the early spring growth in 1955 following the late date of sowing in 1954, viz., 25 August. In the second harvest year although S.170 only produced 6% more total herbage its spring production prior to 20 April was 85% greater than from the S.24 swards. Between 16 April and 7 May the S.170 swards provided 79 steer-grazing days and the S.24 swards only 48 steer-grazing days per acre, i.e., the S.170 maintained $3\frac{3}{4}$ steers and S.24 maintained $2\frac{1}{4}$ steers per acre in this spring period.

During each season three steers were kept regularly on each of the swards for approximately six months with no change of herbage and their weights were recorded throughout the season. In 1955 the steers gained 2.04 lb. per day on S.170 and 1.62 lb. on the ryegrass swards, whereas in 1956 the increases were 1.31 and 1.36 lb. per steer per day respectively. In addition, in 1955 the steers grazing on the S.170 swards showed more " bloom " than those on the S.24 swards; there was no apparent difference between the two groups of animals in 1956.

In 1955 the cattle finished grazing the plots early in September

on account of the shortage of grass, but considerable herbage growth occurred in October and November. Herbage samples taken on 9 December showed 700 lb. of herbage (dry matter) on the S.24 and 530 lb. on the S.170 swards. This herbage was consumed *in situ* by ewe lambs, 15 lambs per acre being maintained by each of the swards for the period 9 December 1954, to 24 January 1955, without supplementary feeding. During this 6½ week grazing period some lambs increased in live weight and others decreased. On an average the lambs grazing the ryegrass swards lost 1½ lb. and those on the tall fescue lost 1/5th lb. during this winter period. At the end of the grazing period the lambs grazing the tall fescue swards had a slightly better " bloom " than those on the ryegrass swards.

Hill land investigations

Studies relating to the improvement of hill land were continued at four centres, namely Llety-ifan-hên, Bwlchrosser, Bwlchcrwys and Pwllpeiran. At the two former centres the investigations were mainly concerned with the influence of treatments on the botanical composition of the native sward, and at the two latter with hill swards improved by cultivation, manuring and reseeding.

Improvement of the native hill sward (*W.E.J.M.*). Most of this work was commenced prior to 1950. The main trial consists of fenced manurial plots at three centres, one on *Molinia* sward and two on fescue/bent swards, on hill farms at 850 to 950 ft. above sea level. The plots have received fertilizers and/or ground limestone, and are grazed by sheep on a monthly rotational basis. The results of the trial from 1930 onwards showed an improvement in the yield of herbage, and an increase in the proportion of the better grasses. In subsequent years in the majority of the plots a further marked increase in yield followed the entry of lowland grasses, white clover and herbs where they have formed robust colonies amongst the native species. During the period 1950 to 1956, some plots have shown a further improvement in botanical composition, the lowland grass species and the clover having increased their contribution to the total herbage. Unfenced plots receiving the same amount of fertilizers have continued to improve in composition, and show a marked superiority in palatability over the surrounding untreated hill herbage. Volunteer grasses and white clover have also, to some extent, come into the herbage of these open plots, especially where complete fertilizers have been given. At intervals throughout this experiment soil and herbage samples are taken from the plots for chemical analysis by the Agricultural Chemistry

Department of the University College of Wales. These results have shown a very great improvement in the nutrient value of the herbage from the treated plots at all centres, corresponding to the improvement in botanical composition.

The work on hill pasture improvement was extended in 1947 when in addition to treating unfenced or open hill areas with fertilizers and ground limestone, grass and clover seeds were sown on the surface of the existing herbage. Marked changes were brought about on *Molinia* and fescue/bent hill swards, by this treatment. The native herbage became more palatable, and following the increased intensity of grazing and treading by farm stock, mainly sheep, wild white clover and better grasses established on the fertilized areas. In order to continue the study of this method of hill pasture improvement further trials were put down during the current period. In all trials the surface-sown clover and grasses have yielded substantial amounts within two to three years.

Plots of representative hill sward types have been cut for hay and aftermath instead of grazing, and have been under a series of manurial treatments, and although they have yielded less than the corresponding grazed plots, they have shown interesting changes in botanical composition.

Improvement of hill land by ploughing, manuring and reseeding. This involved a study of reseeding following the complete destruction of the native swards. Two aspects of this problem were studied, namely (a) the establishment, persistency and general behaviour of various strains of grasses under the conditions prevailing on the hills and (b) the measurement of the relative production of the improved swards with that of the native sward in terms of sheep production.

The former study was conducted on a private farm whilst the latter was a continuation of a trial commenced in 1944 at the headquarters farm of the Cahn Hill-Improvement Scheme.

Establishment. A study of the behaviour of various strains of grasses sown in 1949 at Bwlchcrwys, 1,000 ft. above sea level, was undertaken by Peter Walters, a Ministry of Agriculture post-graduate scholar.

The grass seeds were sown in June with 2 lb. of rape and ½ lb. of turnips as a cover crop. The grazing of the rape and turnips was delayed till October and November, by which time they had undoubtedly suppressed the normal development of the grasses, particularly the Italian ryegrasses, H1, Irish perennial ryegrass and the commercial strains of timothy, tall and meadow fescues.

The results in 1950 indicated that most grasses suffered severe plant casualties in the following winter.

Another trial was laid down on adjoining land in 1950 to study the influence of seeding year management on the establishment of the grasses and their ability to survive the first winter. The variations in management were chiefly the degree of soil consolidation at time of sowing and the grazing of the cover crop.

(a) *Soil consolidation.* Following the ploughing in the winter of the rough hill grazings the area was thoroughly cultivated and limed in the spring. Seeds and fertilizers were sown at the beginning of July after the land had again been cultivated, and finally the whole area was rolled. In order to test the influence of further consolidation, a tractor without any implements attached was run over certain strips of land so that every inch of the soil on these strips was pressed down by the tractor wheels. Three weeks after sowing it was evident that the extra consolidation by the tractor wheels had encouraged the germination and growth of the grasses and checked the development of bracken fronds. By the middle of September the establishment of the grasses and clover under the extra consolidation was 20% and 30% higher than on the area receiving normal consolidation. On the other hand, although the extra consolidation had little influence on the number of rape and turnip plants it had a markedly depressing effect on their growth. The data also indicate that perennial ryegrass and timothy benefited from the extra consolidation, but cocksfoot was hardly affected.

The influence of extra consolidation is illustrated by the following figures :

	Amount of consolidation	
	Normal	*Extra*
Number of bracken fronds appearing per 100 sq. yds.	30	13
Mean dry weight, oz. per plant		
Rape	1.02	0.68
Turnips	2.61	1.60
Establishment of grasses per 2½ sq. ft. in autumn of seeding year		
Perennial ryegrass	172	324
Timothy	456	620
Cocksfoot	317	304

The development of the cover crop varied considerably over the area investigated. Bracken fronds appeared on most of the area, and it was noticeable that more and bigger fronds per unit of area developed in the seeding year where the cover crop made the most vigorous growth. In the following year only a few bracken fronds appeared and the area has been virtually free of bracken since the second harvest year.

(b) *Date of utilization of cover crop.* To study the influence on sward development of date of grazing a rape and turnip cover crop, a portion of an area reseeded at the end of June 1950 was grazed during the latter part of September, and the remainder towards the end of November. Plant counts made in February 1951, indicated that on an average the delay in grazing the cover crop in 1950 reduced the establishment of the sown grasses by about 30% ; this was more pronounced in the Italian and perennial ryegrasses, meadow and tall fescues than for cocksfoot and timothy although there were marked differences between the strains of each species. When it is realized, however, that the growth of the cover crop in 1950 was well below average, and that the winter 1950–51 was rather mild, one can hardly fail to appreciate the importance of controlling the growth of crucifer cover crops on upland areas to ensure a satisfactory " take " of grasses and clover.

Persistency of strains (Ll.I.J. and A.H.C.). The plots at Bwlchcrwys were under observation throughout the period 1950–56. The management consisted of sheep grazing, and during most of the year the sward was kept very short, particularly in late winter and early spring. Although there was a very wide range of variation in the persistency of different strains within a species, the perennial ryegrasses as a group persisted far better than the other species. The outstanding sward in the seventh harvest year, 1956, was formed by S.23 perennial ryegrass, and during that season perennial ryegrass and white clover contributed over 80% by weight of the total herbage on the S.23 plots. The persistency of the different grasses into the sixth and seventh harvest years at this centre is illustrated by the following data regarding ground covered by the different species and strains :

Percentage of ground covered by sown grasses in 1956	*Strains*
Over 75	S.23 perennial ryegrass
60–70	S.101 and S.24 perennial ryegrasses
50–60	Danish late and New Zealand perennial ryegrasses, S.50 Timothy
30–40	Irish perennial ryegrass, S.53 meadow fescue
0–15	S.22 and Irish Italian ryegrasses, H1 Short Rotation ryegrass, S.215 and Danish meadow fescues, S.170 and Alta tall fescues. All timothy strains except S.50. All cocksfoot strains.

Production of improved and native swards (Ll.I.J.). A trial to compare the production in terms of sheep, of a natural unimproved hill pasture with two improved hill pastures, was commenced in 1944 at an altitude ranging from 1,100 to 1,250 ft. on a slope around 1 in 5 with S.W. aspect.

The natural vegetation of this area consisted mainly of fine-leaved fescue and bent, with small amounts of *Molinia*, *Nardus* and fern, but no clover. The area of 27 acres was divided into three blocks :

Blocks A and B (8½ acres each), ploughed and reseeded,

Block C (10 acres), natural herbage, untreated and unmanured.

Blocks A and B were originally cultivated, manured and re-seeded in 1934. Between 1934 and 1944 they received the equivalent of three tons of ground limestone and 12 cwt. of basic slag per acre. Both areas were ploughed again in the spring 1944, cultivated and the seeds mixtures sown early in July with 6 cwt. of basic slag and 1 cwt of nitrochalk per acre. Since the seeds were sown in 1944 the areas have received

12 cwt. of basic slag per acre in 1950
6 ,, ,, ,, ,, ,, 1954
2 tons of ground limestone per acre in 1952

The seeds mixtures in lb. per acre were :—

Perennial ryegrass	12 lb.
Cocksfoot	6 ,,
Timothy	6 ,,
Italian ryegrass	10 ,,
Crested dogstail	½ ,,
Wild white clover	1 ,,

The mixtures differed in that the ordinary commercial strains of perennial ryegrass, cocksfoot and timothy were sown on Block A, whereas similar amounts of the Station's bred strains of these three grasses were sown on Block B. Italian ryegrass, crested dogstail and wild white clover were identical for both areas.

Since the autumn of 1944 every plot has maintained a regular flock of sheep for approximately nine months of each year ; during the period mid-January to mid-April all sheep are brought to lower land common to all three groups. The same rams are used for each of the groups so that all lambs are half-brothers or half-sisters and the differences between the three groups of sheep are not due to breeding.

All sheep are weighed periodically through the season, graded for condition, and valued in the autumn at the normal time of drafting ewes and lambs from hill farms. The following table indicates the relative lamb production from the three pastures, average for the period September 1950–September 1956 :

	Native hill pasture unimproved (Block C)	*Improved hill pasture sown with Commercial strains (Block A)*	*Leafy bred strains (Block B)*
Average number of ewes grazing per 10 acres	15	25¾	26¼
Total number of lambs reared per 10 acres during the six year period	71	172	182
Lambs reared per 100 ewes*	79	111	115
Average weight per lamb**	43 lb.	53 lb.	56 lb.
,, value ,, ,, **	50/-	69/-	73/-
Average weight of lamb produced per acre per annum	52 lb.	142 lb.	155 lb.
Average value of lamb produced per acre per annum	61/-	183/-	201/-
Total value of lamb produced per acre in six years	£18 6 0	£54 18 0	£60 6 0

* Figures relate to the total number of lambs reared per 100 ewes of 2 yrs. old and upwards. The high lamb numbers in Blocks A and B are due to a proportion of twins and lambing by yearling ewes.

** Lamb data at weaning based on single lambs.

The figures show that during the seventh to twelfth harvest years the improved hill pastures carried over 70% more ewes than the unimproved pastures and that the higher fertility of the ewes resulted in more than double the number of lambs. The increased number of lambs reared, coupled with bigger and better conditioned lambs, caused a marked difference in the value of lamb produced per acre. The value of lambs produced per acre on the hill swards formed by sowing the leafy bred strains of grasses was 10% higher than that from swards formed by sowing commercial strains and three and a half times as much as the production from the native unmanured swards.

OTHER INVESTIGATIONS

Agrotype trial

This trial was designed to compare the behaviour of five strains of ryegrass subjected to cutting treatments in the absence of the grazing animal when grown at different geographical locations in the British Isles; it was sown during late July/August 1953, at seven centres, viz :—Bicton (Devon), Hurley (Berkshire), Cambridge, Aberystwyth, Belfast, Newcastle-upon-Tyne and Aberdeen. The trial at Aberystwyth was undertaken by Miss Alison G. Davies, a Ministry of Agriculture post-graduate scholar.

The perennial ryegrass strains were Irish, New Zealand, Kent, S.24 and S.23, grown as spaced plants, pure grass swards and grass/clover swards, under five different systems of cutting treatments, and the investigation was completed in October, 1955. The data from the various centres are now being collated and the following results have already emerged.

Ear emergence. There is a distinct delay in the date of heading as one proceeds north, particularly for early-flowering strains, and the time interval between date of ear emergence of the early-flowering and the late-flowering groups of ryegrasses is reduced. This is illustrated by the following average figures for 1954 and 1955, all dates being calculated relative to the date of flowering of the early-flowering strains at Bicton = 0.

	Bicton (Devon)	*Aberdeen*
Early-flowering strains	0	19
Late- ,, ,,	29	37½

Although the results were not identical for the two years 1954 and 1955, the data suggest that at the western centres ear emergence was a few days earlier than at the eastern centres in a similar latitude.

The ranking of ear emergence was not entirely constant amongst the five strains at the different centres.

Single plants versus *swards*. The yield of spaced plants gave little indication of the strain's performance under sward conditions. When grown as spaced plants the high tillering strains were the more productive ; in swards the early–flowering strains were superior to the late–flowering.

Swards with and without white clover. The influence of white clover on the yield of the swards varied with location, treatment, and the companion strain of grass; (a) location : at Aberdeen white clover increased herbage production by only 8% whereas at Aberystwyth the increase was more than 50%, other centres were intermediate ; (b) treatment : in general the white clover was more abundant and had a greater influence on the yields of the sward the more often they were mown ; (c) strain : the high tillering strains of grasses were generally more aggressive towards the white clover and benefited less by its inclusion in the sward.

The variation in the influence of clover on the total yield of herbage resulted in a different order of ranking of the strains in the pure grass swards and in the grass/clover swards.

Seasonal production of herbage. Although the annual yield of herbage varied considerably between the early and late strains, the extent of the variation was not spectacular. When, however, the growth during a particular period of the year is considered there is a marked difference in the relative production of the strains at the different centres and one seldom finds the same order of production at any two centres for a particular growth period.

Studies on the roots and storage organs of herbage plants (A.T.). Investigations have been directed to the study of the growth of roots, their influence on the soil, and the correlation between root and shoot growth of young plants.

The first investigations showed that under established swards the weight of roots and leaf bases amounted to between 12,000–

20,000 lb. of dry matter per acre. Regular sampling of two grass fields throughout 1950 and early 1951 showed that the amount of roots and storage organs on these fields varied during the year, being low in October/November and high in the May/July period. Slight depressions in April and June suggested reduced root weights when early spring growth commenced, and during the flowering period respectively. Between July and the October/November period the root weights suffered a substantial loss of dry matter equivalent to over 30% of the total root weight in July.

A study of the vertical distribution of the underground plant material in established swards up to a depth of 24 inches showed that 80% was concentrated in the top three inches, 90% in the top six inches and less than 5% in the soil between 12 and 24 inches below the surface. This decrease in the weight of the underground parts of plants in successive layers illustrates the shallow nature of the root distribution of herbage plants, particularly when the plants are mainly grasses.

In 1951 the investigations were extended to include a study of the influence of herbage plants on the organic content and physical condition of the soil. Five seeds mixtures were sown at four centres in Wales and the border counties. The seeds mixtures, all containing white clover, were based on perennial ryegrass, cocksfoot, timothy, meadow fescue, and a mixture of these species.

Root development varied considerably from one centre to another, probably due to a combination of factors, and the following table indicates that a relationship exists between root weight, organic carbon and water-stable soil aggregates :

Centre	*Period*	*Average weight of roots (lb. per acre) 1952 and 1953*	*Percentage*	
			Organic carbon	*Water-stable aggregates*
Manorbier	1952–53	6,900	2.1	51
Talgarth	1952–56	9,000	2.0	50
Munslow	1952–56	10,200	3.1	75
Aberystwyth	1952–53	14,300	3.8	77

Although the relative root development of the different grass swards varied slightly from centre to centre, the perennial ryegrass swards and the mixture (mainly perennial ryegrass) produced the greatest amount, and the cocksfoot swards the least amount, of roots in the first two years. The following figures illustrate the variations from sward to sward :

Sward	Root development lb. per acre	Percentage Organic carbon	Water-stable aggregates
Cocksfoot	9,500	2.4	62
Timothy	10,300	2.5	64
Meadow fescue	10,900	2.6	62
Perennial ryegrass	11,500	2.6	64
Mixture (mainly perennial ryegrass)	12,000	2.7	63

Another experiment was laid down in 1951 to study the production of roots by four grass swards, submitted to four systems of management. The swards were based on S.101 perennial ryegrass, S.26 cocksfoot, *Agrostis tenuis*, and *Festuca rubra*, S.184 white clover being included in each mixture. The managements, confined to two seasons, 1952–1953, were :

(i) moderate grazing in spring, summer and autumn ; (ii) hard grazing in spring, moderate grazing in summer and autumn ; (iii) hard grazing in autumn, moderate grazing in spring and summer ; (iv) mown for hay and aftermath in June and September respectively. During 1954 all plots were cut for hay in June and then grazed.

The botanical composition of these swards exerted a greater influence on root production than the various managements practised. The root weights ranged from 15,000 lb. per acre for S.26 cocksfoot to 17,700 lb. per acre for S.101 perennial ryegrass, whereas within the managements adopted the root weights ranged from 15,300 lb. per acre for the mown plots to 16,700 lb. per acre for the swards subjected to hard grazing in the autumn.

An analysis of the data collected throughout the experimental period shows that the weight of roots of each species increased during late winter and early spring of each year, but that the actual date on which the maximum weight of roots was recorded varied from species to species.

Ley fertility experiments to study the influence of leys on soil fertility have been laid down on a number of Experimental Husbandry Farms attached to the National Agricultural Advisory Service. In 1953 and succeeding years the Welsh Plant Breeding Station was offered facilities to study the root development of the leys at two centres, viz., Rosemaund (Herefordshire) and Trawscoed (Cardiganshire).

The experiments are of a standard design and consist of the following main treatments :

(i) An arable rotation including a one-year ley ; (ii) three years arable and three years grass/clover ley—grazed ; (iii) three years arable and three years grass/clover ley—herbage conserved ; (iv) three years arable and three years lucerne ley—herbage mainly conserved ; (v) long term grass ley.

In addition each plot is subdivided for the application of two levels of nitrogenous manuring.

The data obtained from these swards up to 1956 show that the weight of roots and leaf bases varies from year to year. The differences between the centres and the years are shown by the following figures which give the average weight of roots and leaf bases of all swards in lb. per 1/1000 acre :

Year of sampling	*Trawscoed*	*Rosemaund*
1953	7.0	—
1954	9.3	20.3
1955	10.9	12.8
1956	6.6	5.1

The influence of the different leys on the weight of root and leaf bases at the two centres, expressed in lb. per 1/1000 acre, is shown in the table below :

	Trawscoed	*Rosemaund*	*Average*
1 year ley	4.5	9.4	7.0
3 year lucerne ley	8.4	13.6	11.0
3 year grass/clover ley grazed	9.8	12.9	11.3
3 year grass/clover ley conserved	11.2	15.0	13.1
Average	8.5	12.7	—

A comparison of the swards developed under two levels of nitrogen application showed no consistent effect of nitrogen on the amount of roots and leaf bases.

Open-cast coal site. The soil on an open-cast coal site on part of a field near Llanelly was moved and stored whilst mining operations were in progress. It was later restored and after cultivation and manuring the whole area was reseeded with a seeds mixture based mainly on perennial ryegrass and cocksfoot. In 1953, six years after reseeding, there was a good sward over the whole field and at that time it was impossible to distinguish by eye the disturbed and undisturbed portions. During that year, in collaboration with the N.A.A.S., samples were taken to compare root development and soil characters of the two parts of the field. This is shown by the following figures for two depths of soil :

	Undisturbed soil		*Disturbed soil*	
	0″–3″	3″–6″	0″–3″	3″–6″
Weight of roots + leaf bases (lb. per 1/1000 acre)	19.3	1.9	12.3	2.0
Percentage organic carbon	7.6	6.0	4.1	4.5
Percentage water–stable soil aggregates	84	86	52	47

These figures show that there are still quite marked differences between the two soils.

Studies of the relationship between root and shoot growth of grasses have been confined to the development of the grasses in their seeding year. The conventional method of reporting the relationship between shoot and root growth is by expressing it as a ratio, i.e., weight of shoot per unit weight of root, etc. This ratio changes with age and size of plant and thus difficulties arise when comparing the root/shoot development of different species or of the same species grown in different environments.

A study of the results obtained in the root investigations has shown that the relationship between root and shoot development may be expressed by the allometric formula viz. $y = bx^k$, where $y =$ weight of root, $x =$ weight of shoot, $k =$ ratio of their log growth rates, and $b =$ value of y when x is equal to unity. The values of b and k were constant for a strain over a period of time provided the environment was not changed and the plant remained in the same phase of growth. In these studies it was found that the actual values of b and k depended on the species or strain of herbage plants, the phase of growth of the plant, i.e., vegetative or reproductive, and the environment, e.g., the density of the plants, the nature of the companion plants and the soil fertility.

Germination and establishment of rush (Juncus effusus)

A field-by-field survey of an extensive area in North Cardiganshire was conducted by A. Lazenby, now of the School of Agriculture, Cambridge, in order to ascertain the extent of rush infestation of grasslands.

Investigations showed that the companion species exerted a marked influence on the establishment and development of the rush seedlings. Soil fertility had no effect on initial establishment, but in the absence of companion plants the rushes made far more growth under high fertility. When grown with companion plants under high fertility conditions fewer rush seedlings established, they made less

growth and suffered a higher mortality rate than under low fertility. On the other hand, the rush plants which germinated early after sowing generally made more growth under high fertility conditions than under low, even in the presence of companion plants.

Although soil moisture appears to be the factor which produced the most marked effect on germination and establishment, the companion species also exerted an important influence. This is illustrated by the following data which show the relative number of rush plants established :

Water level	*None*	*Companion plants*	
		Perennial ryegrass + white clover	*Agrostis tenuis + white clover*
At soil surface	100	78	65
2″ below soil surface	33	22	13
4″ ,, ,, ,,	4	0	2

It was interesting to note the influence of the companion plants on the development of the seedlings, shown by the following figures :

Relative weight of rush plants	*Water table*	
	Soil surface	*2″ below soil surface*
Sown alone	100	18.0
,, with perennial ryegrass and white clover	14	0.1
,, with *Agrostis tenuis* and white clover	13	0.3

Epidermal characteristics of the leaves and lemmas of some common British grasses. (I.D.). The possibility of using characteristics of the leaf epidermis as aids to the identification of some British agricultural grass species in the vegetative condition has been studied. The following species were found to be separable on the basis of the epidermal characters of the leaves :

Tall fescue (*Festuca arundinacea*) from meadow fescue (*F. pratensis*)

Heath-grass (*Sieglingia decumbens*) from smooth-stalked meadow grass (*Poa pratensis*)

Sheep's fescue (*Festuca ovina*) from mat-grass (*Nardus stricta*), wavy hair-grass (*Deschampsia flexuosa*) and bristle-leaved bent (*Agrostis setacea*)

Timothy (*Phleum pratense*) from meadow foxtail (*Alopecurus pratensis*) and bent (*Agrostis* spp.).

Small samples of races or species with varying chromosome complements within the genera *Poa*, *Holcus*, *Dactylis* and *Phleum* were also studied. This work was prompted by finding (i) that leaf-blades of *Festuca pratensis* ($2n = 14$) were free of differentiated elements in the inter-nerve epidermis, whilst *F. arundinacea* ($2n = 42$) had cork cells at this location; (ii) that a parallel situation occurred in *Poa*, between *P. trivialis* ($2n = 14$) and *P. pratensis* ($2n = 50$–124). In all the genera it was found that cork cells were generally more abundant in races or species of higher chromosome number.

The lemma in various strains of *Lolium perenne*, particularly Aberystwyth S.23 and S.24 was examined; broadly speaking there were two patterns of distribution of asperities over the surface and differences in the proportion of these two types of lemma suffice to distinguish between S.23 and S.24 seed samples.

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SEED MULTIPLICATION

By Gwilym Evans

The first strains of grasses bred at the Station were released to the Seed Industry for multiplication in 1932 ; they included strains of perennial ryegrass, cocksfoot, timothy and meadow fescue, making a total of six leafy strains. At that time only a relatively small acreage was devoted to grass seed production in England and Wales, although large acreages of red and white clovers were harvested for seed annually.

Before these leafy strains could make a substantial contribution to farm practice reasonable seed yields were required to be produced from them, farmers had to be found both able and willing to grow the seed, and seed merchants anxious to acquire stocks of the seeds regularly. These conditions were fulfilled ; techniques were evolved to produce satisfactory seed yields, grass seed crops were successfully integrated into various systems of farming and all the leading seedsmen listed the strains as standard features of their catalogues. Agriculturists came to appreciate the concept of strain within species and purchased the seeds under their appropriate symbols.

The exigencies of the war years (1939/45) stimulated the production of home-grown seeds of leafy strains on a large scale. By 1940 eleven strains of grasses and three of clovers had been released to the Seed Industry, and in that year, 1,522 acres were grown for seed on contract for merchants. By 1947 the annual total had increased to 36,272 acres so that the United Kingdom became substantially self-supporting in seed of some species, especially of cocksfoot, which had previously been imported in large quantities.

A national committee, the Aberystwyth Seeds Co-ordinating Committee, had been established several years before the 1939/45 war. Its primary function was to bring together leading seed growers, seed merchants, consumers and the Aberystwyth breeders in order to promote seed production of the new strains produced by the Station. Early in the war this Committee was formed into the Aberystwyth Seeds Sub-Committee of the Seed Production Committee of the National Institute of Agricultural Botany, and became concerned with the rapid increase of the seed supplies of bred strains of grasses and clovers, authenticating the seed crops, and each year fixing the prices to be paid to the seed growers for the cleaned seed.

Seed crop authentication had been sponsored by the Station since 1923 when the Montgomeryshire Late-Flowering Red Clover Seed Growers' Association established the first seed crop certification scheme in the Kingdom. In 1940 the Station complied with a request from the Seed Trade to establish a Seed Crop Certification Scheme for the Aberystwyth strains of grasses and clovers, and for the first few years the whole of the inspection work was undertaken by the Station's personnel. Thereafter Agricultural Advisory Officers were given courses of training at Aberystwyth to qualify them for inspecting the seed crops on behalf of the Station. Standards of crop purity in the field and of isolation from other crops of the same species were established for the guidance of inspectors, and certificates were issued by the Station in respect of the standing crops which qualified.

Only seed crops grown from Stock Seed of these strains were eligible for certification; an emergency provision, however, was made whereby certain seed crops grown on contract for merchants and found to be of a high standard were recommended for multiplication by the inspectors and released for the purpose when Stock Seed was in short supply. These stocks were designated Supplementary Multiplication Seed (S.M.S.) to distinguish them from Stock Seed supplied direct by the Station.

To get maximum seed yields from the leafy strains of grasses considerable attention was devoted to the investigation of suitable techniques. It was found that excellent seed crops could be produced by leafy strains when grown in wide drills without a cover crop, the depressing effect of which on seed yield in the first harvest year disappeared from the crops of further harvest years. The converse effect was shown by a substantial reduction in grain yield of barley when undersown with Italian ryegrass.

The seed yield of spaced plants of cocksfoot was found to increase approximately in proportion to the distance between them (6, 12 and 18 inches) and the ratio of fertile to barren tillers also increased with the spacing, but the yield of seed per acre did not vary greatly. No significant differences occurred in seed yields of a pasture strain of ryegrass when the rates of sowing in broadcast stands varied over a wide range.

Although nitrogen doubled the seed yields of some leafy strains of grasses, the yield of red fescue was halved by the same treatment. Potash increased red clover seed yield by 100%, potash and phosphate acting together increased the yield by 148% which

showed their importance for seed production on soils in which they were deficient.

Studies on the effects of spatial isolation on the purity of red clover seed crops indicated that the acreage of the crops and the density of bloom were factors of even greater importance than the distance between crops of different strains.

Although satisfactory seed yields were obtained from the extreme high-tillering, late-flowering strains of grasses, lower seed yields were produced than from the ordinary strains; the early-flowering bred strains, however, produced seed as abundantly as the commercial strains notwithstanding their leafiness.

The results of studies of moisture content in grass seeds provided guidance for applying suitable treatment to stocks for satisfactory storage after harvest, without immediate loss in viability; storage requirements were found to vary in different species.

The first cereal varieties released by the Station were selections of Welsh " land " varieties; they included two Hên Gymro wheats, two selections of Ceirch-du-bach oats, and of Ceirch-llwyd (*Avena strigosa*) oats. These were followed by several varieties of winter and spring oats produced as the result of hybridization, and designed for higher yields of grain and to serve mechanized agriculture better than the older types. Some of these were superseded by varieties showing a greater degree of improvement and for a wider range of soil fertility and climate. Several are now standard varieties throughout England and Wales, especially the winter types. When their superiority became generally appreciated by farmers these new types largely replaced the old " land " varieties as well as those produced by breeding processes; the three varieties which soon gained widespread high reputation were S.147, S.172 winter oats and S.225 spring oats.

The Station in 1933 encouraged the Clarach Valley Seed Growers' Association near Aberystwyth to establish the first Cereal Seed Crop Certification Scheme in Britain; S.78, a selection of *Avena strigosa*, had the distinction of being the first variety to be subjected to field inspection and certification. Other Seed Growers' Associations in Wales and England followed the lead of the Clarach Association in authenticating seed corn

STRAINS OF GRASSES AND CLOVERS

By the end of the 1939/45 war the strains of grasses and clovers bred at the Station had become standard ingredients in seeds mixtures for leys required to function longer than two years, and

became predominant in some mixtures for long leys by official recommendation, to the exclusion of ordinary strains and uncertified seeds. This rapid development of the replacement of the ordinary varieties of commerce by bred strains imposed exceptional demands on the resources of the Station when it was required to provide the stocks for final multiplication by the Seed Industry. An annual flow of Stock Seed had to be maintained on a large scale to produce authenticated seed crops to meet the needs of the country.

Special techniques have been developed for the production of stocks with a high standard of quality and in quantities to correspond with the demand. As 18 bred strains have been established, including several strains within species, considerable land resources are needed to provide adequate isolation for growing Foundation Seed ; in addition to the regularly recurring production of basic seed of these strains, limited stocks of several potential strains must be produced concurrently for agronomy trials.

It may be necessary to increase stocks from mother plants through several generations before sufficient quantities of multiplication seed become available to meet the needs of the Industry to grow contract crops ; the number of stages or generations required for this purpose depends on the nature of the species and strain and on the overall annual demand for Stock Seed.

Foundation or breeders' seed

Foundation or Breeders' Seed is that grown by the Station for the production of Stock Seed which in turn is the grade recognized for the production of Certified Seed. As it has been found that grass strains, especially the high-tillering, late-flowering growth forms, show a distinct tendency to a ' shift ' in type from generation to generation, endeavours are now made to establish clone islands, derived from mother plants for the production of recurring basic seed stocks. By this process it is possible to reduce to a minimum the number of generations of seed between the breeder and the farmer-consumer and thus preserve the type originally produced by the breeder.

To obtain adequate protection for these clone islands from pollen of other varieties and strains only one strain per species is normally grown on each farm unit for seed and for fodder. Thus if four strains of perennial ryegrass are bred and each proves to be of superior value for a specific purpose, four different centres are required for clonal islands. The Station has land now under its control at four such centres for the production of basic lots of herbage seed, namely

(a) Frongoch Farm, (b) Upper Morfa, (c) Lower Morfa and (d) Gogerddan. Frongoch Farm will in future be used primarily for the production of basic seed stocks of herbage seed and of cereals.

For the strains normally grown for seed in wide drills, such as bred strains of cocksfoot, fescues and timothy, sufficient Foundation Seed may be grown direct from clones of mother plants to produce Stock Seed constituting the second generation. Certified Seed grown from Stock Seed on contract by merchants would, therefore, represent the third generation. Only third generation Certified Seed should thus be commercially available when the increase stages are restricted to these three, and a sufficient flow of second generation Stock Seed is maintained annually.

The extent of a clone island of a particular strain is calculated from the estimated quantities of Stock Seed required by the Industry. If, and when, the demand for a strain increases substantially it is desirable to expand the clone island rather than to produce the extra quantity of seed required by multiplying through one further generation. It is convenient to plant the clones in wide rows to allow for cultivating operations to keep the area clean. Distances between plants in a row may vary according to the strain ; wider spacings are possible for very robust strains. Spacings of 24 to 30 inches allow cross cultivations and reduce the necessity for hand–hoeing for the elimination of seedlings arising from shattered seed.

For strains of biennial grasses and clovers the simplest and most convenient method for the production of recurring basic stocks is to grow the initial seed in islands of mother plants, and apply special treatment to the seed harvested in order to maintain its viability over a long period of years. (This technique is explained in papers published in 1957.) The initial stock is stored after treatment as units in heat-sealed glass containers, so that one unit may be withdrawn each time an initial stock is required for the production of basic seed. It is hoped that by using this technique the stocks can be kept viable and vigorous for at least a quarter of a century. Inevitably this method involves at least one more generation of seed in the process of providing Stock Seed than the clonal method, and for this reason it is more applicable to relatively short-lived strains than for perennial strains.

The following table indicates the scope of the basic seed islands in the process of producing Foundation Seed ; several of the clone islands are only in the first stage of vegetative propagation and are derived from relatively few mother plants.

The scope in 1955 of nucleus seed crop islands grown as a basis for Foundation Seed

Species	Number of strains	Clones	Acreage in Single plants	Wide drills
Perennial ryegrass	3	1.30	–	1.10
Italian ryegrass	1	0.10	–	0.50
Cocksfoot	3	1.50	–	–
Timothy	3	1.40	–	0.50
Meadow fescue	2	0.30	–	–
Red fescue	1	0.16	–	–
Tall fescue	1	–	0.30	–
White clover	2	0.30	0.30	–
Red clover	2	–	0.20	2.00

To provide sufficient Stock Seed to meet annual requirements of strains of grasses and clovers grown for seed in broadcast stands and over extensive acreages, it is necessary to have a greater number of generations than is required for strains cultivated in wide drills.

As broadcast or narrow drill sowings need 3–4 times as much seed as wide drill cultures, the quantities of Foundation Seed and Stock Seed are proportionately greater and the Station, therefore, finds it necessary to multiply the nucleus stocks on a field scale to produce sufficient Foundation Seed. Relatively large acreages of these field scale seed crops are grown on contract outside the Station lands, especially of the clover strains, as the seasons are erratic for legume seed production and reserves require to be accumulated to cover poor harvests.

The most suitable accommodation now assigned to Stock Seed crops will be used to store Foundation Seed stocks including reserves to meet future demands and contingencies. All stocks carried forward are subjected to artificial drying to reduce the moisture content to 8% or less, and placed in moisture-resistant containers. As seeds of clover and fescue strains tend to lose their viability more rapidly under ordinary storage conditions than seeds of the other species under consideration, low temperature rooms are provided for the maintenance of their life over a period of years.

Stock seed production

The large scale provision of Stock Seed by the Station was developed to comply with the provisions of the Seed Crop Certification Scheme whereby only those crops grown from seed supplied direct by the Station were eligible for inspection. It is recognized

that much greater care is required in the process of providing multiplication seeds of these cross-fertile strains than for the self-fertile cereals. Considerable acreages have therefore been grown on contract with selected farmers in suitable areas of various counties, up to 150 miles from Aberystwyth, in an endeavour to supply sufficient quantities to meet the demand for multiplication seed.

Suitable precautions are taken in selecting the fields for growing these stocks to ensure that the cropping history, freedom from weeds and other offending plants, and isolation from possible sources of foreign pollen in neighbouring fields, are satisfactory. The crops are under constant supervision by the scientific staff of the Station during growth, roguing, harvesting, processing and distribution.

In order to produce high quality stocks, growers co-operate by sowing for grazing and/or fodder conservation only the strain of each species that is being grown for seed on the farm. In this way a neighbourhood becomes saturated with the pollen of one strain per species, and contamination is avoided of fields which may be used in future for seed production.

The scope of Stock Seed production of herbage strains may be appreciated by reference to the acreages harvested annually and sown for this purpose in recent years.

Acreages of Stock Seed crops of the Station's bred strains of grasses and clovers harvested and sown—1950–55

	No. of strains		*Acres harvested*			*Acres sown*			*Harvested and sown*
Year	*Grasses*	*Clovers*	*Grasses*	*Clovers*	*Total*	*Grasses*	*Clovers*	*Total*	*acres*
1950	13	4	554	198	752	357	235	592	1,344
1951	13	4	586	263	849	383	212	595	1,444
1952	13	4	415	266	681	360	274	634	1,315
1953	13	4	359	228	587	241	299	540	1,127
1954	13	4	351	324	675	265	166	431	1,106
1955	14	4	437	237	674	280	285	565	1,239

Two new grass strains, S.22 Italian ryegrass, and S.170 tall fescue, have been released by the Station for seed multiplication in recent years making the total of 14 grass strains and four clover strains now in commercial usage. The variation in the acreages of Stock Seed crops sown and harvested from year to year is related to fluctuations in demands for such seed by growers of contract seed crops, and both are closely linked with the price levels to the growers for Certified Seed crops.

When the demand for Stock Seed suddenly declines in sympathy with prices, there may be a considerable surplus of seeds of some strains, as was found, for example, with ryegrass stocks from the 1952 harvest ; in that year the Station had over 1,300 acres of

Stock Seed of herbage strains under its control. As the requirements could not be determined in advance the acreages sown for the Station for Stock Seed production have tended to vary with the demand in the previous season, therefore, when the demand suddenly increased there might not be available sufficient Stock Seed of all strains to cover the requirements. The provision of the Supplementary Multiplication Seed was only a temporary expedient, but it enabled many thousands of acres of pedigree seed crops to be grown, and authenticated, which otherwise would not have been available to the farmers of the United Kingdom. It was recognized, however, that this expedient was undesirable as a permanent measure for equating supplies with demands for Approved Multiplication Seed.

The Station was not equipped with accommodation or machinery to provide these stocks on a national scale and the demand on its resources has, therefore, been heavy. For the past 15 years it has been necessary to improvise buildings, and rent others for storing, processing and distributing the seeds. Although during this period the nation has depended on the Station for providing large quantities of Stock Seed, the improvised conditions were inadequate and unsuitable for establishing substantial reserves to cover possible peak demands and poor harvests as well as to provide stocks for current use. The service required to be placed on a more permanent basis and expanded beyond the proper limits of the work of a breeding station.

Arrangements have, therefore, been made to establish new premises and equipment at the National Institute of Agricultural Botany, and to make additional staff appointments, so that ample supplies of Stock Seed of the Station's bred strains of grasses and clovers may be available for the Seed Industry.

Adequate accommodation is also to be provided for establishing large reserves to cover poor harvests of Stock Seed crops and meet exceptional demands, thus eliminating completely the necessity for resorting to Supplementary Multiplication Seed from outside sources. By the application of appropriate techniques for storage the seeds held in reserve should retain their viability and vigour quite satisfactorily for several years. Clover seeds from a very favourable harvest stored under optimum conditions would be expected to show at least as strong vigour after four years as new seed from a poor harvest and it would often be advisable to use the latter before the former.

TARGET SOWING ACREAGES

The target acreages established by the Aberystwyth Seeds Sub-Committee in 1955 for which Stock Seed of the *S* strains should be provided each year for multiplication, are shown in the table below. To provide for these targets the National Institute of Agricultural Botany is planning to harvest each year the corresponding acreages of Stock Seed. It will be necessary for the Welsh Plant Breeding Station to produce sufficient quantities of Foundation Seed for sowing the Stock Seed acreages required for harvest each year.

Targets of annual sowing acreages for the production of certified seed of S strains and the corresponding acreages of Stock and Foundation Seeds

		Acres	
Species and strain	*Certified Seed*	*Stock Seed*	*Foundation Seed*
Perennial ryegrass S. 23	5,000	402	36.00
,, ,, S. 24	3,000	120	6.00
,, ,, S.101	750	60	5.50
Italian ryegrass S. 22	1,000	54	4.00
Cocksfoot S. 26	2,500	34	0.40
,, S. 37	2,500	34	0.40
,, S.143	4,500	68	0.80
Timothy S. 48	3,000	65	1.50
,, S. 50	250	6	0.12
,, S. 51	850	18	0.50
Meadow fescue S. 53	1,250	33	1.00
,, S.215	1,500	33	0.80
Red fescue S. 59	300	7	0.20
Tall fescue S.170	250	5	0.10
White clover S.100	4,500	288	30.00
,, S.184	3,000	192	22.50
Red clover S.123	2,500	216	46.00
,, S.151	250	22	4.50
Totals	36,900	1,657	160.32

The acreages for producing the Stock Seed crops in sufficient quantities to provide for the target annual sowings are based on moderate seed yields and allow for crop failures. In calculating the Foundation Seed acreages allowances have been made for hazards and for accumulating reserves to meet contingencies.

Inspection of seed crops of herbage strains for certification

During the period under review virtually all the seed crops of the Station's strains of perennial ryegrass, cocksfoot, timothy, fescues and clovers submitted for inspection and certification were grown in England and Wales. This was a remarkable development in view of the fact that the quantities of grass seeds grown in these territories prior to 1939 were negligible, the tradition of this type of husbandry not having been firmly established except on a limited scale in Kent. Since the war seed production of the grass strains has gravitated towards the typical arable areas of England and Wales where lower rainfall and more fertile lands produce the best seed yields.

The total annual acreage grown for seed and subjected to inspection has been erratic over a period of years. From 1950 to 1951 an increase of 40% was shown in the acreage sown for seed compared with a decline of 37% from 1947 to 1948, the fluctuations being in sympathy with the prices determined for the Certified Seed crops. A reduction of 40% in the average price to growers for Certified Seed crops of perennial ryegrass strains in 1952 was immediately followed by a reduction of 43% in the acreage of these strains sown for seed in 1953. An average reduction of 47% on the 1954 prices was made in 1955 following an average increase of 41% in 1954 on the 1953 prices.

There have been occasional deficiencies in supplies of Approved Multiplication Seeds of some of the strains, but the wide fluctuation in the annual acreage of seed crops is more closely related to the prices than to this factor. During the last 5 years the highest annual acreage is over 50% greater than the lowest, but the average acreage for this period is similar to that of the previous 5 years (26,611 c.f. 25,873), although over five times the average for the first 5 year period (4,956).

Wide fluctuations in prices have had a disturbing influence on the quality of seed production husbandry, and the sense of insecurity engendered by sharp reductions has tempted growers to exercise excessive caution in their outlay on fertilizers, also to neglect cultivations, and to employ methods of doubtful efficiency in

The acreages of seed crops of grass and clover strains submitted for inspection between 1940 and 1954

Species and strain		1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	*Total for 15 years*
Perennial ryegrass	S. 23	465	533	1,203	1,692	3,538	4,262	6,266	7,850	5,643	4,794	5,250	4,542	4,664	2,640	2,588	55,930
,, ,,	S. 24	16	25	10	—	13	37	—	—	361	501	697	1,068	989	548	674	4,939
,, ,,	S.101	118	92	160	344	722	1,556	3,349	3,221	1,744	1,194	1,228	1,943	1,806	1,032	619	19,128
Italian ryegrass	S. 22	—	—	—	—	—	—	—	—	—	—	—	—	162	145	313	620
Cocksfoot	S. 26	233	227	212	480	1,090	1,881	3,301	3,631	2,103	1,871	2,227	3,338	3,901	2,753	2,357	29,605
,,	S. 37	37	53	65	235	803	1,426	2,244	2,346	1,435	1,452	1,627	2,874	3,342	2,403	1,957	22,299
,,	S.143	172	172	244	326	772	1,664	3,567	3,937	2,245	2,036	2,676	5,155	6,037	5,018	4,004	38,025
Timothy	S. 48	27	7	36	88	325	715	1,128	2,064	1,639	1,703	1,426	2,302	3,373	3,058	2,816	20,707
,,	S. 50	20	—	—	—	3	4	38	87	18	77	84	233	327	387	261	1,539
,,	S. 51	27	10	42	107	74	134	346	613	522	446	515	870	1,074	929	694	6,403
Meadow fescue	S. 53	10	3	16	11	19	45	38	31	59	135	118	168	581	686	1,078	2,998
,, ,,	S.215	—	—	—	8	5	4	35	99	94	334	572	1,225	1,511	1,016	833	5,736
Red fescue	S. 59	74	44	42	18	14	27	65	150	198	322	448	344	428	385	555	3,114
Red clover	S.123	136	162	32	567	1,120	908	896	1,701	413	977	808	1,085	693	648	529	10,675
,, ,,	S.151	—	—	76	79	370	376	587	406	76	458	261	529	329	83	167	3,797
White clover	S.100	188	242	1,044	1,173	3,691	4,760	7,504	8,076	4,832	3,477	2,385	2,860	2,198	2,622	3,066	48,118
,, ,,	S.184	—	—	307	255	259	869	1,353	2,060	1,287	1,263	1,252	1,563	1,279	812	1,016	13,575
Total		1,523	1,570	3,489	5,383	12,818	18,668	30,717	36,272	22,669	21,040	21,574	30,099	32,694	25,165	23,527	287,208

an endeavour to cut their costs. Unfortunately such reactions reduce quality and purity, and increase the cost per lb. of seed, when the cost could be reduced by the application of the most efficient techniques.

In order that the inspection of field crops could be made on a uniform pattern the Station organized the annual Refresher Course of three days' duration for the inspectors, who are mainly drawn on a temporary basis from the National Agricultural Advisory Service from each of the counties of England and Wales where substantial acreages of *S* strains are grown for seed. Officers new to the technique of inspection are given a special Trainees' Course and thereafter assist established inspectors for one or two years to gain experience in the field.

The detailed inspection reports were submitted to the Station with the recommendations of the inspectors concerned, so that decisions could be taken on the merits of the crops, and certificates issued under the signature of the Director. For the past five years over 133,000 acres of seed crops of the Station's bred strains have been inspected, making a total of 287,208 acres for the past 15 years.

In 1955 it was mutually agreed to transfer responsibility for the administration of the Seed Crop Certification Scheme of the Station's bred strains to the National Institute of Agricultural Botany, which body in future will be responsible also for providing refresher courses for inspectors. Members of the Welsh Plant Breeding Station staff will assist with lectures and demonstrations at these courses, and Inspector-trainees will be provided with an annual course at Aberystwyth as in past years.

Maximum annual quantities of seed of *S* strains produced

Experience has shown that it is possible for this country to grow all the grass seed it requires for sowing hay and pasture land. With a sound system of carry-over we could even be self-supporting in red clover seed. These objectives have not been achieved, although in some years high proportions of seeds of the Station's strains relative to the total consumption of all the strains per species have been harvested, as the following table shows.

Maximum annual acreages and percentages of estimated weights of seed from S strains produced in relation to all the seed per species required for consumption

Species and strain		*Year harvested*	*Maximum acreages of seed crops inspected in any one year*	*Estimated percentage weights of S strain seeds produced of the total weights required in 1952 for U.K. consumption*
Perennial ryegrass	S. 23, S.101	1947	11,070	11
Late-flowering red clover	S.123	1947	1,701	20*
White clover	S.100, S.184	1947	10,136	75
Timothy	S. 48, S. 50, S. 51	1952	4,774	28
Meadow fescue	S. 53, S.215	1952	2,092	47
Cocksfoot	S. 26, S. 37, S.143	1952	13,280	91

* Percentage of all late-flowering red clovers.

The contribution of the two ryegrasses S.23 and S.101 to the total seed of all the perennial ryegrass required for home consumption is comparatively low, but in relation to the annual usage of the late-flowering, high-tillering types it is relatively high. In recent years, however, the acreages of these two strains grown for seed have been reduced to less than one-third the 1947 acreage. Since 1948 the acreages of S.100 and S.184 white clover crops grown from Approved Seed for certification have been reduced each year to less than one-half the 1947 level. Several thousands of acres of the clover strains are, however, harvested for seed each year outside the Seed Crop Certification Scheme.

Timothy, meadow fescue, and cocksfoot acreages have been maintained better in recent years relative to their maximum acreages than the ryegrass and white clover strains. The peak of 13,280 acres of the Station's strains of cocksfoot grown in 1952 was estimated to produce 91% of all the calculated national requirements.

for cocksfoot seed, this compares favourably with the 18% of *all home grown* cocksfoot seed ten years previously including seed from 521 acres of *S* cocksfoot strains.

An arrangement has been made between the Station and the Ministry of Agriculture of Northern Ireland, whereby Stock Seed of S.22 Italian ryegrass is provided annually for seed multiplication in that territory. This seed is used for the production of Certified Seed from which Certified Once-Grown S.22 seed is grown for commerce. The authorities in Northern Ireland and the growers are satisfied up to the present with the performance of S.22 in respect of seed yields, seed germination and fodder productivity. Quantities up to 400 tons per annum of Certified Once-Grown S.22 seed may be expected to be produced under this Scheme during the next few years. It is proposed that authenticated seed of this strain will ultimately be distributed in Northern Ireland to replace the ordinary commercial variety for the growing of the 4,000 to 5,000 tons of seed produced annually for Great Britain.

CEREALS

The oat varieties bred by the Station are multiplied through several stages to produce Foundation Seed stocks required by Seed Growers' Associations and Seed Firms as a basis for the production of authenticated seed.

Nucleus stocks

Most of the nucleus stocks of the oat varieties are produced in two or three stages at the Station's Frongoch Farm, Aberystwyth. In order to maintain the purity of the stocks 500 typical heads of a bred variety are taken as a basis, and each head is threshed separately and sown in a 2–3 ft. length of drill. In the process of rigorous roguing, any off-type plants are removed by eliminating the whole drill or drills in which they may appear, as well as the adjacent drills. All the drills are harvested and threshed separately and the produce of each is then sown in a separate double-drill plot ; all the plots of a variety at this stage cover altogether nearly an acre of land. Distinctly off-type progenies or doubtful types are again eliminated, if present, by discarding the whole plot. This is done as early as possible before harvest. Seed derived from this second stage is used direct to produce Foundation Seed on a field scale or reserved to provide a stock each year for several years for the production of the third stage nucleus with which to grow Foundation Seed.

FOUNDATION SEED

Foundation Seed of the oat varieties is largely grown at the Station's farm, Morfa Mawr, Llanon, about 12 miles south of Aberystwyth. Over 400 acres of Foundation Seed oats have been grown on this farm during the last five years from nucleus stocks produced at Frongoch Farm.

To ensure as high purity as possible in these stocks each field is allocated a definite variety of oats, so that whenever a *cereal* crop is required to be grown on a particular field only the designated oat variety is eligible for it. Roguing of the seed fields is facilitated by blocking the middle spout of the drill, so that a path separates each drill width.

Morfa Mawr is equipped with its own threshers, seed cleaning, seed dressing and other machinery for the production of high grade multiplication seed. Fortunately, the land is remarkably clear of such weeds as wild oats, wild onion, wild radish, wild vetch, and shepherd's needle. Since the Middle Ages, when Morfa Mawr was a grange for Strata Florida Abbey, the farm has had a reputation for the production of malting barley and seed corn.

The Station produced the following quantities of Foundation Seed of its oat varieties during the last five years.

Variety	*Year released*	1951	1952	1953	1954	1955
				cwt.		
S.147 White winter oats	1938	230	164	177	132	408
S.172 ,, ,, ,,	1940	227	245	220	206	354
S.225 ,, spring ,,	1947	601	642	663	553	623
S. 84 ,, ,, ,,	1938	200	316	198	127	140
S.221 ,, ,,	1948	379	242	291	199	100
S.220 Black ,, ,,	1945	133	85	61	46	100
S.171 Grey diploid ,,	1935	5	–	8	4	–
		1,775	1,694	1,618	1,267	1,725

The demand for Foundation Seed of the two winter varieties S.147 and S.172 and of spring oats S.225 has been maintained at a high level for many years, in fact the supplies require to be apportioned each year among applicants. The other four varieties of oats have been bred for lower levels of fertility, especially S.220 and S.171 and the demand for them is less than for varieties in the first

group. Although S.84 has now been withdrawn from the Recommended List, Foundation Seed is still in demand for certain areas.

The variety S.171 derived from a cross between *Avena strigosa* and *Avena brevis* bred for poor land conditions has an improved grain yield over the old " land " variety Ceirch-llwyd (*A. strigosa*). It is officially recommended as suitable for use in the Western Isles of Scotland and Certified stocks from Wales are still in demand although the distance for transport is very considerable.

Stocks of pure-line selections from Welsh "land" varieties are maintained and issued from time to time as the need arises. These varieties again are adapted for low fertility levels and include S.70 Hên Gymro wheat, S.79 Ceirch-du-bach oats, and S.75 Ceirch-llwyd (*A. strigosa*).

A new variety of oat is in process of being multiplied for the provision of Foundation Seed in anticipation of its addition to the Recommended List. This is Powys (S.226) a white winter oat designed for a fertility level between S.147 and S.172.

Seed crop certification

During 1939/45 war years the Welsh Seed Growers' Federation established a Comprehensive Seed Crop Certification Scheme for cereals grown by various Seed Growers' Associations. Later a Field Approval Scheme was inaugurated in England, and has been operated by individual seed firms as well as by Seed Growers' Associations. These organisations are given preference in the distribution of Foundation Seed of the Station's bred varieties, so that the best possible use may be made of them, and special growers are selected to grow Stock Seed for members. By exercising exceptional care it is possible for crops of Stock Seed standard to be grown from Stock Seed for several generations without resorting to a new supply of Foundation Seed, but in practice most firms find it necessary to apply to the Station at frequent intervals for limited supplies of Foundation Seed.

Stock Seed is used to produce Certified Seed or Field Approved Crops according to the scheme operated by an organisation. The proportion of the crops rejected on the field on inspection because of impurities is reduced substantially when Stock Seed of a high standard is sown, and measures are taken to plan the cropping so that no offending volunteer cereals should appear in the crops grown for certification.

A measure of the importance attached to the Station's bred varieties of oats by seed firms and farmers may be realized from the

acreages of seed crops of all varieties submitted for inspection under the Field Approval Certification Scheme in England. The total acreages in 1955 of S.147, S.172, and of Milford (S.225) constituted 80% of all varieties. Greater importance has been attached to the growing of winter oats since the advent of the S.147 and S.172 varieties.

INVESTIGATIONS

The inherent characteristics of the bred strains of herbage species, and the virtual absence in England and Wales of experience in seed production of grass species, made investigations on the techniques of seed multiplication, and on the maintenance of stocks, matters of urgent necessity. Since the release of the bred strains, and the subsequent commerical multiplication for seed on a large scale, seed growers, seed firms and Advisory Officers have looked to the Welsh Plant Breeding Station for guidance on methods that could be successfully used for the seed production of the different strains on a farm scale. Much of the experimentation is, therefore, of direct significance for contemporary seed husbandry.

The effect of seed rate and nitrogen on seed crops of leafy grass strains: 1. Wide drills (G.E.)

Leafy strains of perennial ryegrass S.23, cocksfoot S.143, and timothy S.48 were spring sown in wide drills 24 inches apart without a cover crop at the rates of 1, 5, 25 and 125 lb. per acre respectively, and seed crops were taken for successive harvest years from the stands. In order to study the effect of nitrogen on the seed crops the following average quantities per acre of elemental nitrogen were applied, in autumn and in spring, for each harvest: perennial ryegrass 69.44 lb., cocksfoot 95.48 lb., timothy 82.46 lb.

Although the primary purpose of selecting the range of seed rates was not for the study of their effects on seed yields, the results presented in the following table are of considerable interest and economic importance.

Mean yields of seeds in lb. per acre from different rates of sowing, without and with nitrogen

Species and strain	*No. of harvest years*	*Seed rates per acre*								*L.S.D.*	
		Without nitrogen				*With nitrogen*				$P = 0.05$	$P = 0.01$
		1	5	25	125	1	5	25	125		
Perennial ryegrass S. 23	3	427	397	314	282	608	632	597	585	65.68	87.78
Cocksfoot S.143	4	271	199	145	128	470	422	341	317	44.45	59.41
Timothy S. 48	4	299	256	237	225	405	342	326	331	36.74	49.10
Mean for the three species		332	284	232	212	494	465	421	411		

The general trend of these data indicates that the mean seed yields of each species were reduced as seed rates were increased. With or without applications of nitrogen the yields have not been increased significantly by sowing above 1 lb. per acre.

Nitrogen increased the yields at each of the sowing rates but decreased the differences between the yields at the different rates. Cocksfoot showed the greatest mean increase with nitrogen and timothy the least, the greatest relative increase being at the heaviest sowings.

Nitrogen significantly increased the number of *fertile* tillers in each of the three species, but was not altogether efficacious in correcting the depressing effect of excessive seed rates on fertile tiller numbers. The effect of nitrogen on both fertile and barren tiller production is illustrated by the following data for S.48 timothy.

Number of tillers per unit area for S.48 timothy

Seed rate lb. per acre	*Without nitrogen*					*With nitrogen*					*L.S.D.*	
	1	5	25	125	*Mean*	1	5	25	125	*Mean*	$P = 0.05$	$P = 0.01$
Fertile tillers	72	68	52	47	60	110	123	118	103	114	17.08	22.83
Barren tillers	58	63	82	82	71	21	27	31	29	27	10.06	13.44

It will be observed that without nitrogen the number of barren tillers increased and the fertile tillers decreased as the seed rates were augmented. Fertile tillers predominated at the lower rates, and barren tillers at the higher rates. Nitrogen has effected a remarkable degree of conversion of barren into fertile tillers, so that the mean number of seed-bearing stems is over four times that of vegetative shoots instead of there being a predominance of the latter.

THE EFFECT OF SEED RATE AND NITROGEN ON SEED CROPS OF LEAFY GRASS STRAINS : 2. BROADCAST (J.L.)

Leafy strains of perennial ryegrasses S.101 and S.23 were sown at four centres, broadcast, for seed, in replicated plots ; four seed rates 4, 12, 16, and 20 lb. per acre were used, with or without 1 lb. per acre of wild white clover. Two levels of nitrogen were applied in spring at 1½ and 3 cwt. per acre nitrochalk (15.5% N.).

The results derived from the four centres showed no significant changes in mean yield by varying the seed rate within the range of 4 to 20 lb. per acre, which confirmed previous results obtained at the Station.

The addition of clover depressed the yield of ryegrass seed significantly; the adverse effect was most marked at the two centres where considerable lodging occurred.

Nitrogen applied at the higher level of 3 cwt. per acre nitrochalk raised the mean yield of the ryegrass seed significantly above that obtained from the lower level. Where, however, the crop was apt to lodge the higher application of nitrogen was often deleterious to seed yield.

Mean seed yields of perennial ryegrass at 4 centres

Treatment	*Yield cwt. per acre*	*Treatment*	*Yield cwt. per acre*
Without clover	3.74	Nitrochalk at 1.5 cwt.	3.52
With clover	3.53	,, ,, 3.0 ,,	3.75
L.S.D.	0.20	L.S.D.	0.20

P = 0.05

Low yields were produced where lodging occurred prior to anthesis; on the other hand, later lodging was not inconsistent with very high seed yields.

THE EFFECT OF A COVER CROP (H.M.R.)

Seven grass species were sown in drills 2 ft. apart to assess the effects of spring barley as a cover crop on the subsequent seed crops, the barley being sown at the same time as the grass seeds. A measure of the differential effect of the barley on the first harvest year seed crops of the various grass strains can be observed in the following table which shows the relative yields of the seeds as threshed.

		Relative seed yields	
		Without barley	*With barley*
Agrostis tenuis	Br 616	100	100
Perennial ryegrass	S. 24	100	83
Timothy	S. 51	100	78
Meadow foxtail	S. 55	100	50
Meadow fescue	S.215	100	45
Tall fescue	S.170	100	34
Cocksfoot	S. 26	100	32

Agrostis tenuis, and also the early type of perennial ryegrass and the timothy, withstood the competition of the barley much

better than the other species. Perennial ryegrass is the most vigorous of the series in its early stages of establishment, especially after the removal of the cover crop, so that in the spring of the year following sowing it produces abundant shoots capable of developing into fertile tillers for the first harvest year. *Agrostis* and timothy are, however, slower in establishing than the ryegrass but as they are at least a month later in heading they have a longer period in spring for vegetative growth and the development of fertile shoots.

Barley depressed the yields of the other four species to a marked degree ; each of them is much earlier heading than *Agrostis* and timothy and has less time in which to overcome the aggression of the cover crop. Although tall fescue develops into a very robust plant under favourable conditions, it appears even more sensitive to competition in the early stages than meadow fescue.

The harmful effect of barley on the first year crops does not appear to be repeated in the second harvest year seed crops of the above strains.

Drill width effect on yields (H.M.R.)

A comparison has been made of seed yields produced from different drill widths of cocksfoot S.37, meadow fescue S.215 and timothy S.51 sown without a cover crop at 6, 15, 24 or 36 inches apart. Each drill width treatment was subjected to two nitrogen fertilizer levels, applications being made in the spring ; the eight treatments were laid out in a Latin Square design. All plots received 4 cwt. compound fertilizer applied in autumn, with nitrogen applied in March, at 3 or 6 cwt. per acre nitrochalk (15.5% N.). The relative yields of seed for the whole period of the experiment are shown in the following table :

Drill width in inches	6		15		24		36			
Nitrogen treatment	N	2N	N	2N	N	2N	N	2N		
Species and strain	Relative seed yields for three harvest years								Mean	*L.S.D.*
Cocksfoot S. 37	75.7	85.9	99.2	114.8*	102.0	110.3	101.9	109.0	100	12.6
Meadow fescue S.215	112.6	121.6	114.2	125.3	93.4	103.6	58.8	67.0	100	13.5
Timothy S. 51	90.3	99.1	92.5	114.9*	100.4	130.0*	79.2	92.9	100	14.1

P = 0.05

* significant over N.

Nitrogen at the higher level increased the mean yields significantly at the 15 in., spacing for cocksfoot, and at the 15 and 24 in., widths for timothy. Cocksfoot suffered more than the other two species in terms of seed yields by sowing in the closest spaced drills; on the other hand meadow fescue mean yields were better in the 6 and 15 in., spacings than in the wider drills. Timothy appears to be able to produce the higher yields at the standard width of 24 inches.

Aphids were a factor which influenced the seed crops during the first harvest year; meadow fescue in the 36 inch drills suffered extensive damage and in the 24 inch drills it was slightly damaged, but there were only traces of the greenfly in the 6 and 15 inch drills. It would seem that the higher humidity gathering around the growing plants in the narrow drills does not provide a suitable microclimate for the greenflies to thrive, and for this reason alone narrow drills have an advantage over the wide drills for growing the early type of meadow fescue for seed. It could be argued, however, that the yields in the wide drills might have been as good or better in the absence of aphids but, on the other hand, the relative yields in the second and third harvest years were even lower in the wide drills than in the first crop, although the aphids were less in evidence or absent. It remained a fact, however, that the yields in the narrower drills of meadow fescue were superior to those of cocksfoot in any of the drill widths.

The differences in yield of S.37 cocksfoot in the 15, 24 and 36 inch spacings respectively, were relatively small, but this does not imply that the higher tillering *pasture* strains of this species would of necessity react in a similar manner, nor that other strains of timothy would show peak yields grown in drills 24 inches apart.

Inter-drill cultivations and seed yields (H.M.R.)

The effects of inter-drill cultivations made in different months on the seed yields of cocksfoot S.143, perennial ryegrass S.23 and meadow fescue S.215 have been investigated. These grasses were sown in drills 2 ft. apart without a cover crop.

Cultivations of the inter-drill spaces were made in different months from January to May, the plots being randomized for each species, and each treatment was replicated eight times. A sharp-edged spade was used to make vertical cuts 6 ins. deep as close as possible to the plants and parallel with the drills; the ground between the cuts was thoroughly dug and broken up.

For each of the three harvest years of the experiment the applications of 4 cwt. compound fertilizer per acre were made in September, and 4 cwt. of nitrochalk in March. A summary of the results in terms of seed yields is given in the following table.

Mean yield of seeds in lb. per acre per annum for three species, and three harvest years

			Month in which cultivation was made					
Species and strain		*Control*	*January*	*February*	*March*	*April*	*May*	*L.S.D.*
Meadow fescue	S.215	288	339*	336*	291	288	236**	35.66
Cocksfoot	S.143	497	538*	558*	523	501	484	40.17
Perennial ryegrass	S. 23	333	385*	357	375*	354	305	40.32
Mean		373	421	417	397	381	342	

P = 0.05
* significant above control
** ,, below ,,

The above data suggest that the earlier in the year the inter-drill cultivations are made the better are the seed yields and that cultivations after April may be deleterious.

Inter-drill cultivations may be necessary after the turn of the year to complete the destruction of seedlings derived from seed shed during the previous harvest, and it is reassuring to find this might be done with benefit to the seed yield as well as to conform to the requirements for seed crop certification.

FERTILIZER TREATMENTS FOR SEED YIELD (H.M.R.)

Cocksfoot S.26 was sown at 5 lb. per acre in wide drills, 2 ft. apart to study the effect of fertilizers on seed yield. The soil analysis showed a satisfactory lime, phosphate and potash status. Manurial treatments of P = 4 cwt. basic slag (15% P_2O_5), N = 4 cwt. nitrochalk (15.5% N.) and K = 1 cwt. of muriate of potash (60% K_2O) per acre were set out in four blocks so that N, P, and K were confounded. Each block had the following eight treatments : Control, N, P, K, NP, NK, PK and NPK and the fertilizers were sown at the above rates in March of each year for three successive harvest years.

The data from the various treatments showed that nitrogen increased the seed yield significantly for each of the three years ; the response to phosphate was only slight, and not significant in any year. The potash response was significant at P = 0.05 in the first harvest year, but not in subsequent years.

The mean yields summarized in the following table show the main differences obtained.

Mean seed yield over three years in cwt. per acre

		Phosphate		*Potash*		
		Without	*With*	*Without*	*With*	*Mean* (±0.15)
Nitrogen	Without	3.6	4.0	3.6	3.9	3.8
	With	5.3	5.4	5.1	5.6	5.4
Phosphate	Without	–	–	4.3	4.6	4.5
	With	–	–	4.5	4.9	4.7
Mean (±0.15)		–	–	4.4	4.8	4.6

By taking the seed yields for three harvest years in the above table of means, a significant increase in yield of 1.6 cwt. per acre has been produced by the nitrogen factor. The mean responses to phosphate of 0.2 cwt. per acre and to potash of 0.4 cwt. per acre were not significant. These results, taken in conjunction with previous data, indicate that a positive response may be expected from applications of nitrogen on cocksfoot, but that phosphates and potash are less certain to produce increased seed yields.

Inter-harvest grazing and seed yield (H.M.R.)

To study the effects of inter-harvest grazing on seed yields, perennial ryegrass S.101, timothy S.50, cocksfoot S.37 and S.143 were sown in drills 2 ft. apart and subjected to the following treatments : (a) winter grazing, (b) spring grazing, (c) winter plus spring grazing, (d) control. After each grazing nitrochalk (15.5% N.) at 2 cwt. per acre was applied in addition to the standard manuring of 4 cwt. compound fertilizer (NPK. 12 : 12 : 15%), in September, and 4 cwt. nitrochalk in March. The grazing treatments were continued for three successive harvest years, and the results are summarized as follows.

Winter grazing. The seed yields of the pasture strains, S.101, S.50, S.143 were not significantly reduced by winter grazing, but the hay strain of cocksfoot S.37, appears to be more sensitive to hard grazing during this period, the third harvest year yield being significantly depressed.

Spring grazing, and winter with spring grazing. Twice grazing, in winter and in spring, was not more detrimental to seed yields

than the single grazing in spring only, when extra nitrogen was applied after each defoliation. Both the winter plus spring and the spring only (mid-April or later) defoliations reduced the timothy yields significantly in each of the three harvest years. Neither of these two treatments reduced the yields of the late heading strain of ryegrass significantly except when defoliation was delayed until May, and a dry period followed. March and early April grazings of the cocksfoot strains did not affect yields adversely, but mid-April grazings depressed seed production in both.

MAINTENANCE OF LIFE IN SEEDS : 1. RED CLOVER (G.E.)

An experiment was laid down to study the effect on longevity of red clover seed stored under various conditions. Seed germinating 97 % (1.4% hard seed) was stored in glass bottles of half pint capacity as follows :—

Series A (1) Control, (2) Air replaced by CO_2, (3) 20 grams calcium chloride placed under the seed in bottles, (4) Air replaced by CO_2 plus 20 grams chloride. The bottles were stored in a cold store at 32° to 41°F.

Series B was prepared in the same manner as Series A, but the bottles were kept in a laboratory cupboard.

Some of the effects of the storage conditions on germination over a period of years are shown in the following table.

Storage site	*Treatment*	*Percentage germination* *Years of storage*				
		1	3	10	14	23
Laboratory	Control	96	94	0	1	1
,,	CO_2	96	93	1	2	0
,,	$CaCl_2$	95	95	78	70	64
,,	$CaCl_2+CO_2$	98	95	81	78	63
Cold store 32°–41°F.	Control	96	95	92	67	34
,,	CO_2	99	98	95	75	55
,,	$CaCl_2$	97	96	90	76	63
,,	$CaCl_2+CO_2$	97	94	99	82	71

Viability was maintained at a high level under all the conditions for three years. After six to seven years the seed held in the laboratory without calcium chloride had no commercial value, but with calcium chloride germination was considerable even after 14 years.

Viability was maintained at a very high level for ten years in all the lots kept in cold store. A desiccant seemed to be as important as cold storage after ten years. Carbon dioxide favoured longevity, but was less important than a desiccant or cold storage. Vigorous seedlings grew from seed held for 23 years in cold store, or in the laboratory with calcium chloride and carbon dioxide, or with calcium chloride only.

After 23 years' storage in cold store with the desiccant and carbon dioxide the seed had retained perfectly the bright highly-coloured appearance associated with a newly-harvested crop, the greatest discolouration being in the laboratory control lot. Although a considerable proportion of the latter was well coloured, life was extinct except in a very small percentage of the seed.

The elimination of only 2.23% moisture (from 10.32% to 8.09%) was efficacious in preserving for 8 years the life of the seed in sealed bottles in the laboratory at 95% germination compared with 18% for the undried seed. Seed in a canvas bag stored in a winter-heated room germinated 89% after 2 years, but only 27% when stored in an ordinary granary.

MAINTENANCE OF LIFE IN SEEDS: 2. RYEGRASS (G.E.)

Perennial ryegrass seed was dried by means of a heating gradient ranging from 50°C. to 120°C., temperature increases of 10°C. being made regularly at intervals of 3 hours. The figures for germination capacity obtained immediately after treatment indicated that a lethal zone had been reached with final temperatures above 100°C., and moisture contents reduced to 0.09 and 0.00%.

It was shown that heat-drying to as low as 0.66% moisture at a final temperature of 100°C. for 3 hours did not injure the germination capacity over a period of 7 years, but after 15 years a greater loss in viability occurred than in seed lots treated less severely. Germination energy figures (6 days' test) rather than germination capacity are a more reliable guide to optimum temperatures, duration of heating, and moisture content in the drying of seed for long-period storage.

The most favourable treatment in this series was obtained by heating the seed gradually to a maximum temperature of 90°C. for 3 hours with a reduction of moisture content to 1.62% whereby the seed was in a condition to germinate 81% after 15 years; for the first 7 years the seed was stored in sealed bottles in an ordinary room, and for the last 8 years in a cold room after replacing the air in the bottles with nitrogen.

MAINTENANCE OF LIFE IN SEEDS: 3. MEADOW FESCUE AND TIMOTHY (H.M.R.)

Meadow fescue seed lots at 16.6%, 12%, 8% and 5% moisture content, and timothy at 13.5%, 12%, 8% and 5% were stored in (a) cotton bags, (b) cellophane bags and (c) sealed glass bottles in (1) cold store (2) laboratory and (3) granary.

All the lots of meadow fescue seed in bags maintained their viability at a high level for 3 years in cold storage (32°F.±2°). The viability of timothy seed was also well maintained except for the lot dried to 5% moisture.

Viability declined significantly in laboratory storage (54°F. to 67°F.) compared with the viability of seeds in cold storage. The artificial drying before storage retarded the decline in germination capacity.

Granary storage (41°F. to 60°F.) was significantly less favourable for the maintenance of viability than either laboratory or low temperature storage. The seed stored in cellophane bags after artificial drying survived better than in cotton bags, the fabric of of the former preventing the re-absorption of atmospheric moisture by the seeds better than that of the latter.

Seeds of both meadow fescue and timothy dried to 8% moisture content and kept in sealed bottles maintained their germination capacity for two years as well in the laboratory as in the cold store. Viability was not improved by replacing the air in the bottles with nitrogen but the inclusion of anhydrous calcium chloride promoted longevity very substantially.

MAINTENANCE OF LIFE OF SEEDS: 4. CROP AND WEED SEEDS (J.L.)

An experiment was initiated in 1951/52 to study seed longevity in cereals, grasses, herbage legumes and arable weeds held in cold storage (32°F. ±2°), the granary and buried in heavy loam soil at depths of 5, 10 and 15 inches and peat at 10 inches.

Seed life was preserved in each of the groups at a much higher level in low temperature storage than under the other conditions.

In the granary, seed viability declined continuously in all the species over a period of four years; in the cereals life was most persistent in wild oats, followed by cultivated oats, barley and wheat. *Bromus mollis* deteriorated much more rapidly than *Alopecurus myosuroides*. Viability was very high in *Geranium* spp., at the end of the period, whereas in the legumes it was negligible.

Under soil conditions the cereal group declined to an average of

2% viability after one year but *Avena fatua* germinated 3% after 4 years. Among the grasses the highest figures recorded after 4 years at a depth of 5 ins. were *Phleum* 76%, and *Agrostis* 28%. Several other grasses showed a germination of only 4% or less. Relatively high persistency was shown by several weed species, *Chenopodium album* having 83% viability, *Ranunculus repens* 66%, *Matricaria inodora* 60%, and *Plantago lanceolata* 47%. *Geranium* spp., however, showed negligible viability in sharp contrast to their reaction to granary storage. Legume seed viability reached a low level after one year, but a small proportion was still viable after 4 years.

Wet peat destroyed seed life more rapidly than heavy loam soil; among the *Gramineae, Agrostis* was markedly superior in vitality and *Polygonum persicaria* showed considerably higher viability than the other weed seeds.

The order of longevity among genera appeared to vary with the storage conditions, *Phleum* seed, for example, surpassed all other grasses in the soil, but not in granary storage and *Geranium* among the weed seeds reacted conversely. Perennial ryegrass and cocksfoot seed survived better in soil than the fescues. Differential survival within and between the groups studied has an important bearing on the Seed Industry and crop husbandry.

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CYTOLOGY SECTION

By Keith Jones

During the period under review the Cytology Section has been concerned almost exclusively with problems in grasses and the needs of the grass breeder. Consequently the Cytology and Grass Breeding Sections have worked in the closest collaboration to their mutual benefit. It is often the case, therefore, that some problems are investigated jointly.

As the Section has developed, a balance has been maintained between practical problems and those of a more fundamental nature. The work of the Section thus falls into three categories :

(a) Routine counts of chromosome number, or checks on chromosome pairing, in plant introductions, potential and established strains

(b) Detailed cytological studies of plants possessing some agronomic potential

(c) The cytotaxonomy of British grasses.

The following report for the period 1950–1956 deals with these three aspects of the work of the Section

The cytology of *Agrostis* spp. and their hybrids

An investigation has been made of the cytology of British species of *Agrostis* and their hybrids, based on material collected and hybridized by W. Ellis Davies when a member of the Grass Breeding Section. The species concerned were *A. setacea* ($2n = 14$), *A. canina* subsp. *canina* ($2n = 14$), *A. canina* subsp. *montana* ($2n = 28$), *A. tenuis* ($2n = 28$), *A. stolonifera* ($2n = 28$) and *A. gigantea* ($2n = 42$). A full report of this study has already been published, (Jones, Keith, 1956a, 1956b, 1956d.)

Chromosome interchanges in *Lolium perenne*

The study of interchanges in *Lolium perenne* has been carried out over a period of several years and part of the problem formed a contribution to an M.Sc. thesis by Mr. J. Morrow, The Queen's University, Belfast, who worked for some time in this Section. Originally three unrelated plants were found to be heterozygous for an interchange which showed itself as a quadrivalent at meiosis.

These plants were intercrossed in the following combinations $A \times B$, $C \times B$, $C \times A$, and the F_1 plants examined cytologically with particular reference to the presence or absence of quadrivalents. The results of this analysis were as given in the following table.

Cross		Frequency of plants with stated number of quadrivalents 0	1	2	Total plants	X^2	P
A × B	Observed	17.0	16.0	0	33	0.1	0.95
	Expected	16.5	16.5	0			
C × B	Observed	7.0	20.0	24.0	51	14.0	0.01
	Expected	12.75	25.5	12.75			
C × A	Observed	14.0	32.0	22.0	68	2.33	0.3–0.4
	Expected	17.0	34.0	17.0			

These data show that plants A and B are heterozygous for interchanges involving the same chromosomes, whilst plant C is distinct from them in this respect. The proportion of homozygotes to heterozygotes in the progenies accorded with expectation in two instances but departed significantly from it in cross C × B. There is clearly strong selection for interchange heterozygotes, particularly the double heterozygote in this example. As both plants C and B have been shown to give expected segregations when used as ♀ and ♂ respectively in combination with plant A, the C × B result must be the product of an interaction of the genic complexes of these two parents. It is not possible to say at this stage whether this reaction is between major genes or polygenes. Another indication of reaction in this case is the high frequency of plants with anomalies of meiosis as compared with the products of the other crosses. Detailed analysis of quadrivalent formation and orientation etc., in a sample of plants from each cross have shown that orientation is probably under genotypic control.

Cytological survey of ecotypes of *Dactylis*

A cytological survey has been made of a wide range of ecotypes of *Dactylis* spp. from Scandinavia, Europe and the Mediterranean area. Diploids have been found in F.A.O. collections which have originated in Portugal (F.A.O. No. 3602) and Algeria (F.A.O. Nos. 3168, 3215, 3328). The remaining lots are tetraploids ($2n = 28\pm$) with 3.7% of the plants aneuploid ($2n = 27, 29, 31$). *B*-chromosomes ranging in number from 1 to 4, have been found in the Portuguese material and in some tetraploids from Cyprus and Algeria.

Meiotic studies have shown that pairing in the diploids is of the expected type with seven bivalents at first metaphase. Two

plants from different sources were considered interchange heterozygotes because of an association of four chromosomes at this stage. The only observable difference in pairing between the diploid ecotypes was the reduced chiasma frequency per chromosome in the plants from Algeria. F_1 hybrids between the Mediterranean and Portuguese diploids and *D. aschersoniana* and *D. voronovii* show complete and uniform pairing which gives no indication of chromosome differentiation between species.

Chromosome pairing in 64 tetraploids from ten different areas was consistently of the autotetraploid type giving an overall mean of 2.97 quadrivalents per cell : 10.9% of these plants showed higher multivalents in some cells and were judged to be interchange heterozygotes. The analysis of 35 plants representing four commercial and pedigree strains gave a mean of 3.04 quadrivalents per cell. No interchange heterozygotes were detected.

Thirty-seven plants representing the F_1 progeny of six crosses between tetraploid ecotypes showed a slight but uniform reduction in quadrivalent means with an overall mean of 2.49. This is evidence of a small degree of chromosome differentiation. Interchange heterozygotes formed 2.7% of these plants.

The above data have shown that chromosome pairing and quadrivalent formation are uniform and very stable in *Dactylis glomerata*, being unaffected by inter-ecotype hybridization or by selection for fertility during breeding. In this, as in other " autotetraploid " grasses, there is nothing to support the hypothesis of a " shift " to bivalent formation through a process of gradual chromosome differentiation.

Meiosis has been analysed in 20 triploid hybrids from the crosses *D. glomerata* ($2n = 28$) $\times$ *D. voronovii* ($2n = 14$) and *D. glomerata* $\times$ *D. aschersoniana* ($2n = 14$). These gave means of 3.36 and 4.01 trivalents per cell respectively. These and other triploid data indicate that small differences between the chromosomes of diploid types can be more readily detected by their pairing behaviour in such triploid combinations where trivalent formation is a reflection of their capacity to overcome the difficulties of preferential pairing of the *D. glomerata* chromosomes.

Physiological ageing of seeds of *D. glomerata* gives rise to chromosome breakages and reunions in derived seedlings. An experiment has been started to determine the incidence and significance of this type of chromosome mutation in seeds, varying from 1 to 12 years in age, which have not been stored under conditions designed to retain their powers of germination.

Cytology of *Holcus mollis* and *H. lanatus*

An examination of the cytology of *Holcus mollis* has shown it to be a complex species with a number of chromosome forms, i.e., $2n = 28, 35, 42, 49$. Of these, the pentaploid ($2n = 35$) is the most common, due to its greater vegetative vigour and superior adaptability to conditions of soil moisture. Chromosome numbers of a different range are found in seedlings derived from the open-pollination of the above types. These were mainly aneuploids ranging from $2n = 22$ to $2n = 63$, but the fact that these numbers are almost exclusively absent as established plants in natural habitats shows there is little effective reproduction by seed, with the possible exception of the tetraploid ($2n = 28$), which produces a high proportion of tetraploid seed. A clear distinction should, therefore, be made between the *actual* and the *potential* chromosome number of the species.

Although there are no qualitative differences that can be detected between the races of *H. mollis*, studies of chromosome pairing, chromosome morphology and crossing data suggest that the pentaploid has been derived from the hybridization of *H. lanatus* ($2n = 14$) and *H. mollis* ($2n = 28$).

Chromosome studies in *Anthoxanthum*

The analyses of 30 plants of *Anthoxanthum odoratum* ($2n = 20$) from several different localities have shown the species to be cytologically autotetraploid with means of between 2 and 3 quadrivalents per cell. More significantly, however, every plant has at least one association of six or eight chromosomes at first metaphase. In this species, therefore, there is intense selection for interchange heterozygosity and it is one of the purposes of this investigation to assess the nature and significance of this system. Preliminary studies show that the nucleolar chromosomes are usually involved in the interchange and they consequently vary considerably in morphology. Interchanges may have arisen because of the fragile nature of their secondary constrictions.

The origin of *A. odoratum* is being investigated by studies of comparative morphology of the chromosomes of this tetraploid and of the diploids *A. alpinum* ($2n = 10$), and *A. puelii* ($2n = 10$). Triploid hybrids of *A. odoratum* and *A. puelii* produced by Martin Borrill, Grass Breeding Section, are also giving much useful information. There is no evidence at the present time to support the idea that *A. alpinum* is the diploid progenitor of *A. odoratum*.

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CHEMISTRY SECTION

By G. ap Griffith

Prior to 1953 the chemical side of the research work of the Station was carried out in collaboration with the Agricultural Chemistry Department of the College. In October 1953, the Chemistry Section was established and a Senior Experimental Officer, an Assistant Experimental Officer and one Assistant (Scientific) were appointed.

Pasture analysis for crude protein determinations

In March, 1954, with the completion of a chemical laboratory, one of the first tasks of the Section was to deal with the large number of herbage samples which awaited crude protein determination, and during the following year a routine was developed for dealing with them, and with the several thousands of samples which were derived annually from the field experiments. The pattern of the routine was established in consultation with the research chemists at Jealott's Hill and the Grassland Research Institute, Hurley, and in its final form it enabled two operators to deal with eight dozen samples daily. The technique adopted made it possible to dispose rapidly of the accumulated samples and to arrange that only a portion of the year be devoted to the routine protein analysis of samples from agronomy experiments. Since 1955 the crude protein analyses have kept up to date with field experiments.

Technique of fibre assessment

Once this object had been achieved attention was turned to fibre content; the proportion of crude protein alone, though important as an indication of quality is not in itself a complete measure of nutritional value, therefore consideration was given next to the development of an indicator of digestibility.

Having evolved a satisfactory Kjeldahl routine attention was given to the development of a suitable technique for dealing with crude fibre. The official method of determining crude fibre, though giving results which correlate well with dry matter digestibility as assessed by animal experiment, is clumsy and laborious. On the basis of the success achieved by Dr. D. M. Walker, of the Rowett Research Institute, Bucksburn, Aberdeen, in using 5% sulphuric acid for a single digestion, a suitable method was evolved in conjunction with him and Mr. W. F. Raymond of the Grassland Re-

search Institute. This method was designated the "Normal-acid method", which whilst giving as good correlation with dry matter digestibility as the official method, greatly excelled the latter in speed and precision. There is one qualification, however, namely, that the correlation with dry matter digestibility shows signs of varying from one group of roughages to another, which means that the same correlation coefficient will not apply to all types of roughage. To obtain the full precision of which the method is capable the correlation coefficients with dry matter digestibility determined by the animal must be found (possibly at different stages) for all groups of roughages, hay, silage, pasture, and for different herbage species. The proper application of the method at this Station will, therefore, have to remain in abeyance until facilities for feeding trials are made available.

During the months preceding the end of the period under review mineral analyses were made of dung, urine and herbage from an experiment conducted by the Grassland Agronomy Section to determine the effect of the artificial return of fertilizers compared with the natural return *via* the animal on yield etc., of herbage. This work is typical of the routine service which is given by the Chemistry Section to other sections collaborating in experimental work.

Apart from the routine analyses conducted as services for the other Sections the Chemistry Section itself has been engaged in investigating various problems.

Study of chemical and other characters of cereal straw

The first is a study of the chemical and other characters of cereal straw (principally oats) with reference to straw strength, chiefly for susceptibility to lodging. An estimate of the resistance to lodging was obtained by suspending a linked chain from the base of the panicle, and measuring the weight of chain as indicated by the number of links supported by the straw and hanging clear of the ground. This weight divided by the weight of the plant was taken as an index of the resistance to lodging of the straw, and agrees with observed lodging. So far no relationship has appeared between straw strength and chemical composition of different varieties, but this observation does not yet exclude the possibility of strength within a variety, as affected by environment (e.g., fertilizer) being related to chemical composition.

The ammonium and nitrate status of grassland soils

The second line of investigation initiated by the Section has been a study of the ammonium and nitrate status of grassland soils. We are also investigating nitrogen recovery from summer and autumn applications of nitrogen applied as ammonium and as nitrate from split dressings of nitrogen. Preliminary results show a marked advantage in nitrogen recovery of split over single dressings, and also that all evidence of the applications, single or split, has disappeared from the soil in two to three weeks. Nitrate dressings survive for a little less time than ammonium.

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MORFA MAWR SEED MULTIPLICATION FARM

By Llywelyn Phillips

Morfa Mawr, a farm of 463 acres situated on the coast of Cardigan Bay 12 miles south of Aberystwyth, is the property of the University of Wales, and is held by the Welsh Plant Breeding Station on a tenancy agreement.

This farm is considered to be one of the best in Cardiganshire and has maintained a high tradition for seed corn production. The land is relatively fertile and its topographical features provide satisfactory harvesting conditions even in difficult seasons. These factors, together with the proximity of the farm to the headquarters of the Station for the adequate supervision of seed multiplication, make it suitable for the growing of Foundation Seed and Stock Seed of the Station's bred varieties of oats and strains of grasses.

One of the main difficulties in grass seed production is the provision of adequate isolation for different strains of the same species. Morfa Mawr is particularly well placed in this respect, for isolation is satisfactory on the northern, southern and eastern boundaries through the ready co-operation of neighbouring farmers who sow on those fields adjoining Morfa only those strains of grasses grown for seed at Morfa ; the sea delimits the farm on the west.

The long configuration of the farm is divided into two fairly equal sections by a steep bank and cliffside ; seed crops of perennial ryegrass S.23, cocksfoot S.37 and timothy S.48 are grown on one section, and perennial ryegrass S.101, cocksfoot S.143 and timothy S.51 on the other.

In order to avoid the risk of contamination from shed seed a system of cropping has been established whereby each field is permanently allocated for a specific strain of grass and a variety of oats.

Both broadcast and drilled stands of perennial ryegrass are established for seed production ; cocksfoot and timothy, on the other hand, are grown only in wide drills. As a general rule only one seed crop is harvested from a broadcast stand while two crops of perennial ryegrass, and three of timothy and cocksfoot are taken from the drilled stands. Perennial ryegrass is sown broadcast under oats at the rate of 15 lb. per acre together with $\frac{1}{2}$ lb. of wild white clover S.184. After the ryegrass seed crop is taken the field becomes a grazing ley until it is ploughed for oats in the rotation. When sown in 2 ft. drills the seed rate for the grass crops is 4 lb. per acre.

Grass seed crops are normally harvested with a binder and

threshed from the rick, but severely laid ryegrass crops are cut with a mower and threshed from the swath with a combine harvester using a " pick-up " attachment. There is no machinery at Morfa Mawr for processing the threshed grass seed ; this work is done at the Station's Frongoch Farm.

In future emphasis will be laid on the growing of Foundation Seed of grass strains largely derived from spaced clones of original plants required for the production of Stock Seed by the National Institute of Agricultural Botany. This scheme started in 1954 when small areas of cocksfoot S.143, timothy S.51 and meadow fescue S.215 were planted for harvesting in 1955. For the production of Foundation Seed of spring oats a simple rotation is practised, namely, oats, oats, roots and oats, perennial ryegrass for seed followed by the use of the ryegrass stand (with white clover companion) as a ley for several years. Three varieties of spring oats S.84, Maldwyn S.221, and Milford S.225 are grown while stocks of the black spring oat S.220 are produced on a neighbouring farm.

Two successive Foundation Seed crops of each of the winter oats varieties S.147, S.172 and Powys S.226 are followed by a root crop ; these fields are then reseeded direct to a grazing ley for young stock. The oats are cut with a binder, and only occasionally is a combine harvester used. All the oat stocks are processed on the farm and distributed direct to the various seed organizations.

In order to maintain soil fertility and utilize the straw and by-products of seed production the farm is stocked with 146 head of cattle and 190 breeding ewes. The herd consists of pedigree Welsh Black cattle, a hardy dual-purpose strain giving good milk yields with a high butterfat content and bullocks fattening readily on grass at $2\frac{1}{2}$–3 years old. The breeding flock comprises pure bred Welsh Mountain and Clun Forest sheep together with Welsh × Border Leicester ewes, all wether lambs being fattened on rape. The farm is entirely self-supporting financially.

BRIEF DESCRIPTIVE NOTE ON THE NEW WINTER OAT VARIETY POWYS (S.226)

The development of the two winter oat varieties, S.147 and S.172 and their release to farmers just before the outbreak of World War II has been responsible in large measure for the expansion in winter oat growing in those areas of England and Wales where the crop can be successfully grown. Experience with these revealed the desirability for a third variety intermediate in straw length, possessing the grain characters and the yield capacity of S.147. Through repeated selection from the offspring of a cross between S.172 and S.147 made by E. T. Jones in 1940, the new variety Powys (S.226) was developed incorporating many of the desired characteristics. Limited quantities of Foundation Seed of this variety will be allocated annually to Seed Firms and Seed Growers' Associations, priority being given to those operating Comprehensive Certification and Field Approval Schemes for oats.

Powys (S.226) is equal to S.147 and is an improvement on S.172 in yielding ability, grain size and quality ; it is intermediate between its two parents in straw length and panicle characters. It has inherited in large measure the winter hardiness, high tillering ability and good lodging resistance of S.172, and ripens a few days earlier than either parent.

Farmers who grow S.147 should find this new variety a most valuable alternative for fields on which S.147 has shown a tendency to lodge ; fertilizers can be used more generously with less risk of lodging than in the case of S.147 and, unlike many stiff-strawed oats, the straw is not prone to break when allowed to mature for the combine. Powys is intended for soils of medium to high fertility and because of its good tillering a seed rate of 1–1¼ cwt. per acre is generally adequate.

DESCRIPTIVE FEATURES

Straw 6–8 ins. shorter than S.147 ; more resistant to lodging. Panicle open, equilateral, of similar conformation to S.147 but slightly more compact. Spikelets generally two-grained ; mature grain white, medium sized, plump, free from awns and of good quality. Base of lower grains with two small lateral tufts of short fine hairs.

Proportion of husk in the grain = 23–25%
Weight per 1,000 grains = 34–38 gms.

BRIEF DESCRIPTIVE NOTE ON S.100 "NOMARK" WHITE CLOVER

Description

S.100 "Nomark" is a medium-leaved persistent strain of white clover which can be distinguished from its sister strain of S.100, and from other white clover strains, by the absence of the leaf marks characteristic of red and white clovers. The leaves have a darker shade of green than S.100; the stolons are as thick as those of S.100. These two strains flower at the same time.

The origin of the strain is similar to that of S.100; it is the result of breeding and selection amongst plants of English white clover (Kent) and white Dutch clover grown in Australia.

Agronomy

Trials with S.100 "Nomark" have indicated that it resembles S.100 white clover very closely both in regard to its herbage production and its general behaviour in swards. There is some indication however, that under conditions favourable to growth S.100 "Nomark" is more productive than S.100 whilst under less favourable conditions it is slightly less productive. The results obtained at the Grassland Research Station, Hurley, show these strains to be very similar in behaviour. It is intended in due course that S.100 "Nomark" shall replace S.100.

LIST OF RELEASED STRAINS

A full description will be published in Leaflet Series S. No. 6

GRASSES AND CLOVERS

Perennial ryegrass	S.23, S.101, S.24
Italian ryegrass	S.22
Cocksfoot	S.143, S.26, S.37
Timothy	S.50, S.48, S.51
Meadow fescue	S.53, S.215
Red fescue	S.59
Tall fescue	S.170
White clover	S.100, S.100 "Nomark",* S.184
Red clover	S.151, S. 123

*New strain to be released in due course

OATS

Spring varieties

S. 84; Milford (S.225); Maldwyn (S.221); S.220; Ceirch-du bach (S.79); Ceirch Llwyd Cwta (S.171) (diploid); *A. strigosa* (S.75).

Winter varieties

S.81; S.147; S.172; Powys (S.226)

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